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HUMAN ENGINEERING PRINCIPLES APPLIED TO A LABORATORY DEVELOPMEN--ETC(U)

MAY 79 J RHODE, B SIMONSON, J STACY, B FOULKE

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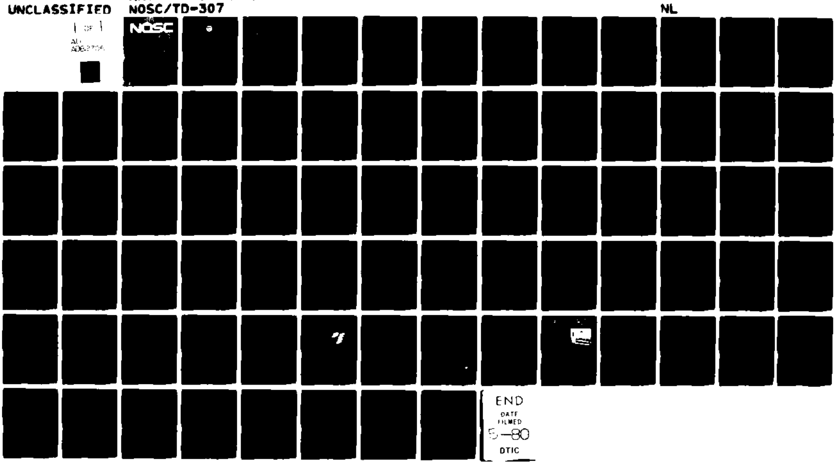

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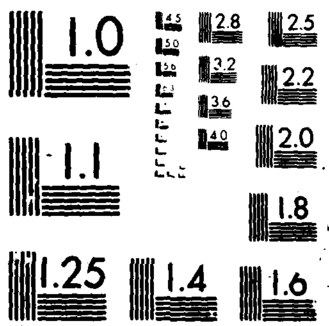

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HUMAN ENGINEERING PRINCIPLES APPLIED TO A LABORATORY DEVELOPMENT MODEL: A DEMONSTRATION

J Rhode and B Simonson
NOSC

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Systems Consultants Inc

22 May 1979

Prepared for
Naval Electronic Systems Command
Code 304

Approved for public release; distribution unlimited

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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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Commander

HL BLOOD
Technical Director

ADMINISTRATIVE INFORMATION

This report was originally prepared as a group project in partial satisfaction of requirements for a college course taken outside of Naval Ocean Systems Center. The subject system is being developed under the sponsorship of Naval Electronic Systems Command (NAVELEX), Code 304.

The authors combined their efforts for this report because of a mutual interest in the development, and the evidence of a need for human factors engineering effort on the system.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Development of complex and technically sophisticated electronic equipment for use aboard ship often proceeds from concept to prototype with little or no consideration of human factors. The introduction of the human operator to the system at the production stage results in requirements for human factors modifications to be retrofit into system designs. An evaluation of the human factors of a laboratory model of a system (Integrated Calibration and Test System) was made to illustrate some of the human design factors to system design engineers and to show that human engineering design should begin early in

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20. ABSTRACT

system developments.

SUMMARY

Project.

This report presents the results of a group effort to examine the "human factors" aspects of a current Navy development. The system examined is approaching the laboratory demonstration stage in its development and therefore could be complemented by the investigations and results. A representative segment of the laboratory model system was used as the basis for this project.

Results.

The examination was done in terms of (a) the information to be passed by the electronic system to the human users and (b) the way by which technicians, as operators, would make use of the system (controls and displays).

Perhaps the most significant and yet most difficult to quantify are the results of part (a). Table 1 shows a comparison of the information seen to be required from the system, as perceived by Navy personnel, with the perceptions of the system designers. The differences can appear to be slight and vastly separated at the same time.

Control and display examinations were more to the point and easily defined. Suggestions and proposals for both areas are made herein.

Table 1.

Comparison Of User Defined vs. Designer Defined Information Requirements

Defined By Navy	Defined by System Designers
Information Flow (Fig. 4, Solid Lines)	Information Flow (Fig. 4, Dashed Lines)
Three (3) Hierarchical Levels, Lowest with two (2) Subdivisions	Three (3) Hierarchical Levels, Excluding Operations Level
Commander Requires Status (System, Subsystem), Estimated Time to Repair (ETR), Equipment Name	Commander and Comm. Officer Require System Status, ETR
Commander Requires System Status Defined M1-M4	Commander Requires System Status (Good,Marginal,Bad)
Command, OPS, and Equipment Level Require Subsystem Status Defined C1-C4	Communications Officer Requires Subsystem Status (Good, Marginal, Bad)
Command and Equip. Level Requires Equipment Name (for Faulty Subsystem)	Maintenance Requires Equipment Name (for Faulty Subsystem)
Commander Requires Supply System Status for Equipment Under Repair	Maintenance Requires Supply System Status for Equipment Under Repair
Maintenance and Supervisory Technicians Require Test Measurement Information	Same

Recommendations.

The project has illustrated to both Navy personnel and system engineers, that developmental systems can have some definite benefits from serious human engineering inputs. A general recommendation is that such inputs be a part of the development process, and that in the case covered by this report, the detailed recommendations of Section IV be incorporated.

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FIGURES

TABLES

I. INTRODUCTION

1. Background.

a. General.

An electronic, microprocessor-controlled monitoring system is being developed for the Navy. Its purpose is to provide performance measurement information to shipboard personnel concerning the operation of a variety of ship systems (called Base Systems). The information provided is to be used by maintenance personnel in the testing and repairing of Base Systems equipment, and by Command personnel in the assessment of Base Systems status (good, marginal, bad).

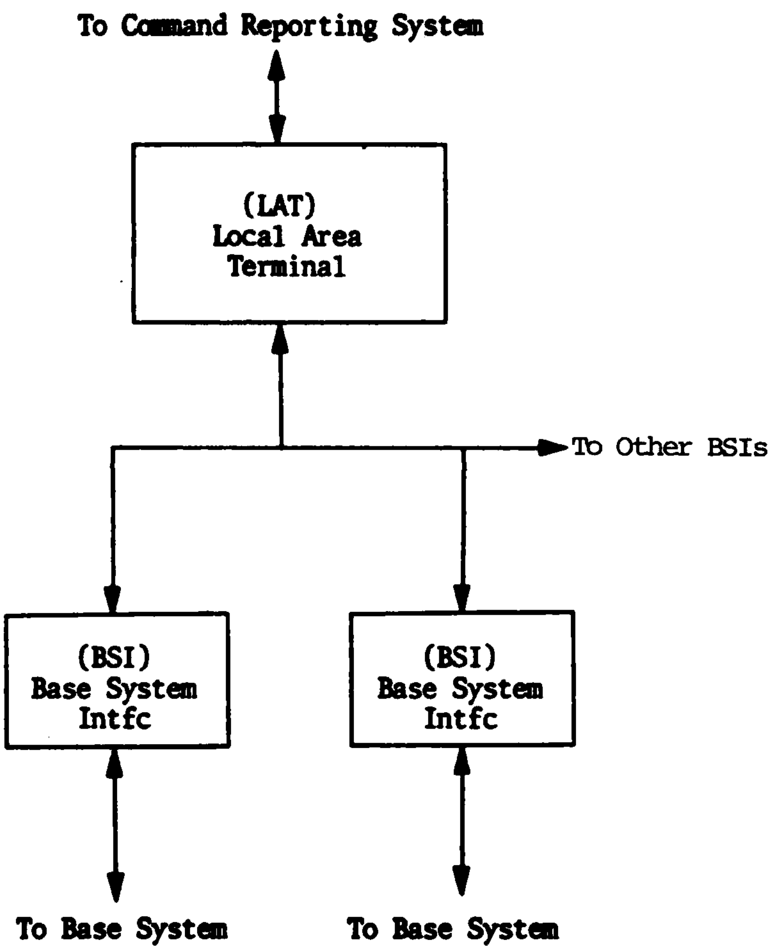
The monitor system will be situated in equipment areas, such as the radio room, aboard ship. It is comprised of two major elements with a suitable connection link between them. (See Fig. 1). The first element is the Base system Interface (BSI) which is connected directly to the Base System equipment and is operated by maintenance technicians in the performance of test and measurement duties. A variety of BSI units may exist in a given equipment area, depending upon the variety of equipment types. Each BSI will monitor all of the equipments of a particular type in any one equipment space.

The BSI is controlled by, and communicates test results to, the second element called the Local Area Terminal (LAT). Control signals and data signals between the BSI and LAT are carried by the connecting link. There will normally be one LAT in each equipment area, although an equipment area could consist of more than one compartment of the ship.

Operators of the Local Area Terminal will either be supervisory maintenance personnel or maintenance technicians. The LAT is the controlling

Figure 1.

Equipment Area Monitor System



element for all of the BSI units connected to it, and it has access to all of the monitor information about the Base Systems.

The LAT will send status data, derived from the BSI measurement information, to Command personnel via an undefined system called the Command Reporting System. (See Fig.2).

b. Laboratory demonstration model.

Communications equipments have been chosen as the intial equipments to be monitored. A test configuration of a monitor system for selected communications equipment has been designed and is being developed for laboratory demonstration purposes. It will consist of two BSI units, of which one monitors a high frequency (HF) receiver type, and the other monitors an ultra-high frequency (UHF) transceiver type. Also included in the demonstration model is a Local Area Terminal. These components of a Communications Monitor System and the information they deal with are the subject areas of this report. (See Fig.3)

2. Purpose of the project.

The purpose of this project is to evaluate the human factors aspects of the design of a Communications Monitor System. This evaluation consists of two parts:

a. The types and amounts of information required to provide the status indication and maintenance measurement functions.

b. The displays and controls to be used by maintenance and supervisory personnel during the operation of the BSI units and the LAT.

3. Scope of the project.

The Communications Monitor System laboratory model will include more

Figure 2.

Command Reporting System
(Connected To LAT)

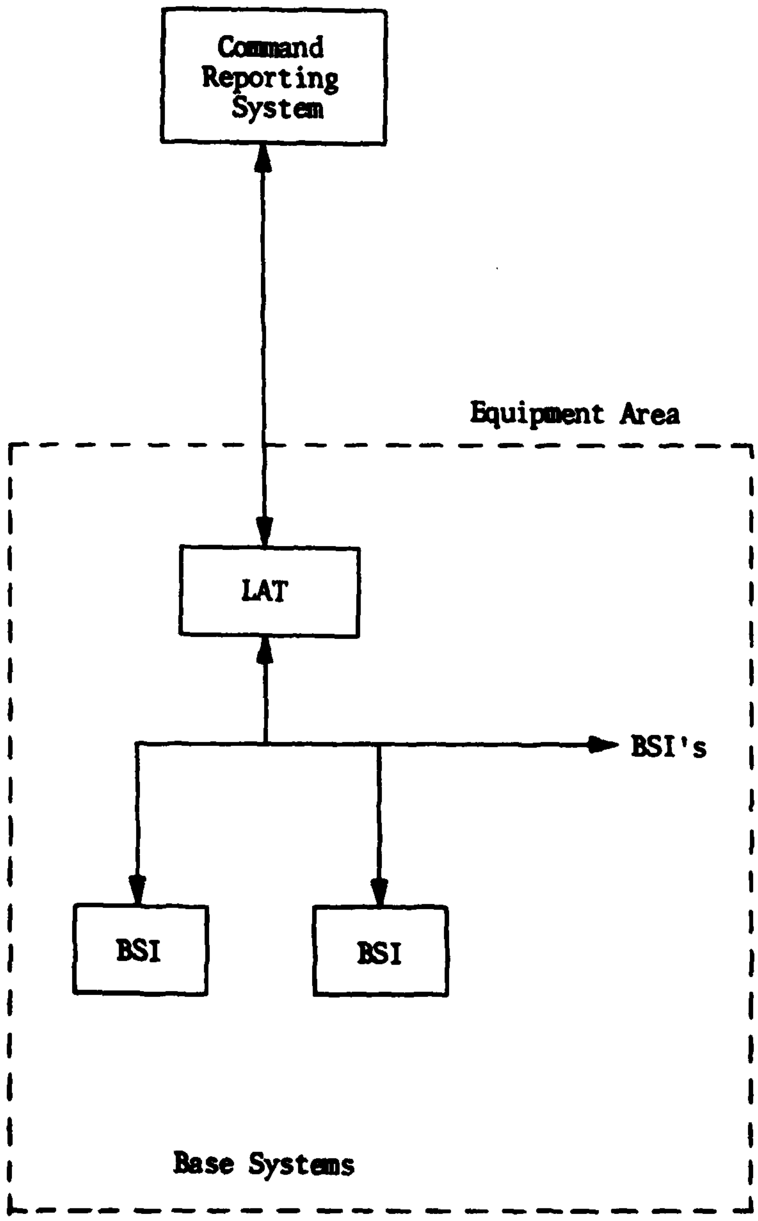
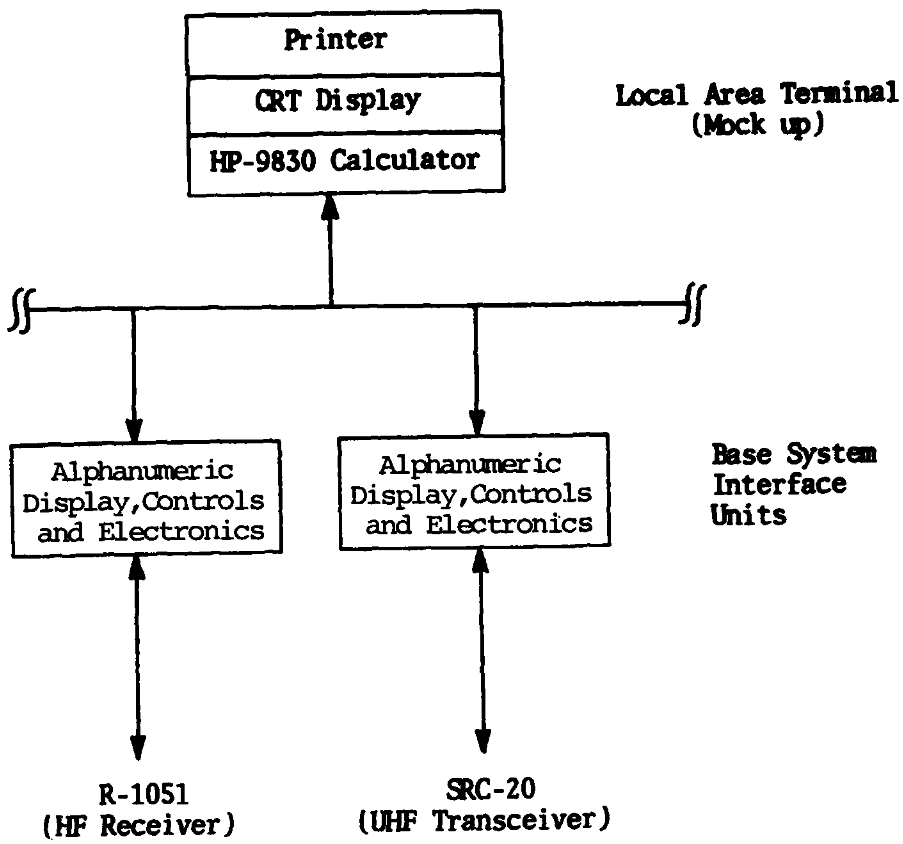


Figure 3.

Communications Monitor System
(Laboratory Demonstration Model)



equipment than is described above. The description given is that of the portion chosen as a suitable class project and as such defines the scope of the project. The points of the evaluation are itemized below:

a. Information requirements.

  (1) Status (command)

  (2) Maintenance (technicians)

b. Controls and displays.

  (1) Local Area Terminal (supervisory technicians)

  (2) Base Systems Interface for HF receivers (technicians)

  (3) Base System Interface for UHF transceivers (technicians)

II. PROCEDURE

1. User requirements study.

Investigations were made into the requirements for information about communications systems by shipboard personnel. Interviews were conducted with active Navy personnel of both Command and Maintenance types. Documents which indicate information requirements were studied. These are maintenance check-off lists for technicians and operational procedures documents for commanders. Interviews and discussions were held with the monitor system designers to determine concepts of user requirements to which the system was originally designed. The results of these two investigations were compared for differences affecting the operation or configuration of the monitor system. Consideration was given to the manner in which the system should be operated, and to the types of personnel who would be operators.

The results of the investigations, comparisons, and examinations are

described and tabulated in Section III. A development of the effort which concerns the automatic production of certain maintenance and logistics forms is included as Appendix A.

2. Control and display evaluation.

a. General.

Each of the BSI units included in this project (HF receiver and UHF transceiver) has an operator control panel design which will be used in the laboratory model. The two completed designs were evaluated against MIL-STD-1472B and other human factors design publications. The evaluation studies were performed with consideration of the manner in which the monitor system is intended to be operated, as determined during investigations of paragraph 1 of this Section. The LAT operator control panel was designed new for this project using the same information and publications as used for the BSI control panel evaluations. The results of the evaluations and design, including diagrams of the control panels are given in paragraph 2 of Section III.

b. Procedure for Evaluating and Designing Controls and Displays.

The basic procedure used to evaluate and design the controls and displays was as follows:

1. Determine the information flow and information display requirements based on the results of the user requirements study.

2. Establish the functions to be performed by the operators and by the equipment at each position.

3. Determine the actions to be taken and the controls to be used by the operators.

4. Determine the characteristics of the planned operators.

5. Establish the operating environment (lighting, background noise, etc) for the equipment.

6. Review military standards on human engineering design criteria and technical books on human factors design criteria related to the design of the controls and displays.

7. Design the controls and displays for LAT.

8. Prepare check-off lists for comparing the designs with documented standards, and complete the lists by evaluating the designs against each criterion on the list. Revise the design if appropriate.

9. Establish operating procedures for using the displays and controls, and evaluate the compatibility of the designs with these procedures in terms of providing a controls and displays layout that provides for efficient operation with a minimal probability of error.

The procedure did not include experiments. Recommendations about the possible use of experiments are provided in Section IV.

III. RESULTS

1. User requirements study.

a. General.

The user requirements (types and amounts of information) investigated were of two general classifications:

-as perceived by potential system users (Navy Command and Technician personnel)

-as perceived by original system designers.

Data were gathered by interviews with a small number of personnel from active

duty Navy and from personnel engaged in design and demonstration of the Monitor System. The determinations made and reported here are subject to much refinement because of the presence of opinion and conjecture.

The general flow of information with regard to communications equipment is shown in Figure 4, solid lines. This flow passes through three defined hierarchical levels (Ref.6), ultimately arriving at the Commanding Officer (CO). A summary of user requirements has been presented in Table 1 on the Summary page, and is repeated here.

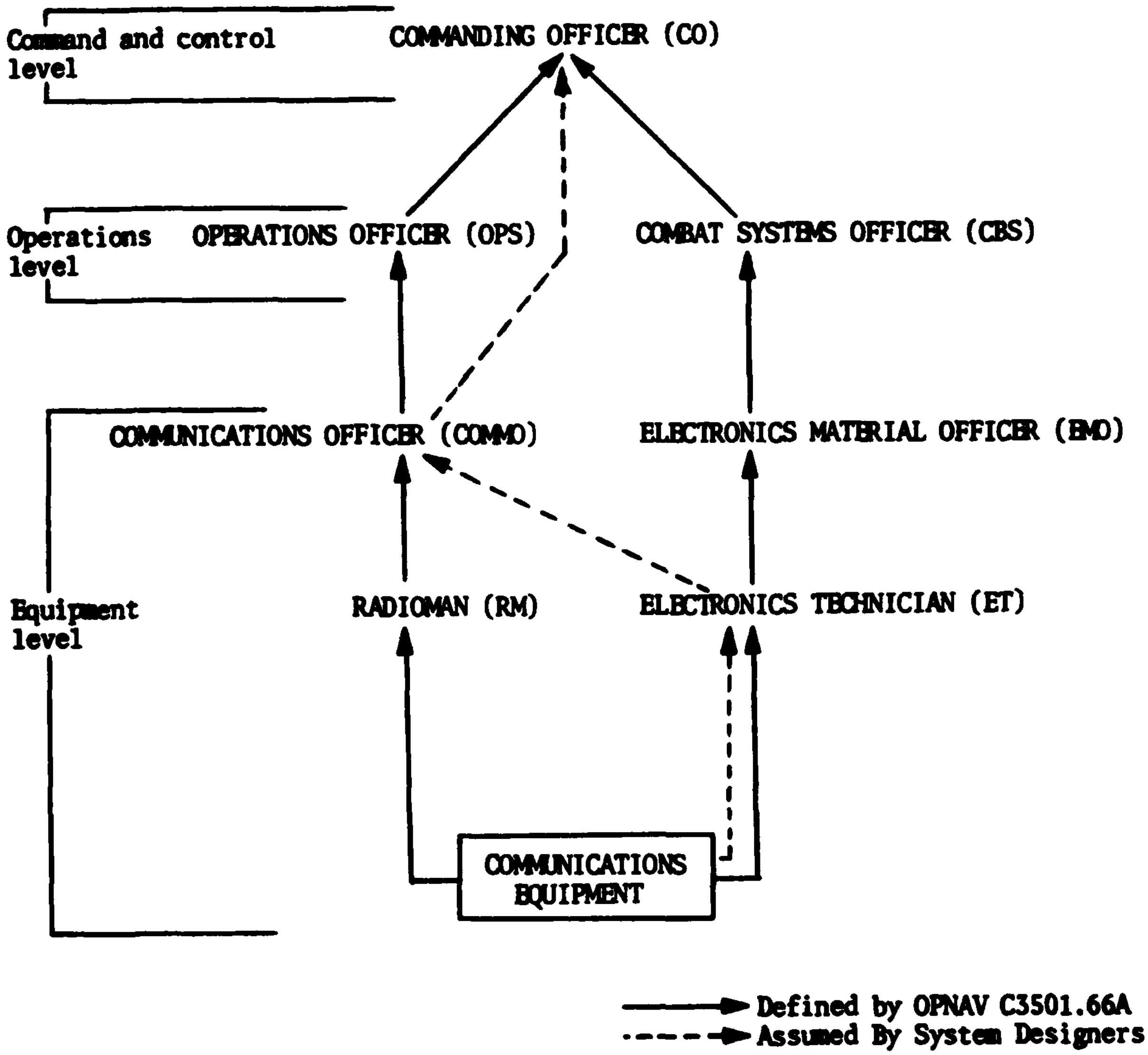
b. Command requirements.

Information required at the Command level regarding communications spans a wider range of detail than thought by the designers of the monitor system. The requirement for information is a function of the operability of the communications system. As the operability decreases, the need for detailed information increases, culminating in an abiding interest in the estimated time to repair, status of the supply system (for the particular repair), and the name of the equipment at fault. Designers had considered that system status (good, marginal, bad) and estimated time to restore were good and sufficient information. Additionally, the requirement for logistics and supply information extends into Command levels to an extent not considered by original designers. More detailed information is presented on this subject in Appendix A.

The highest level of refined information (system status) required by Command is defined as M1 through M4, in descending order of system operability. The characteristics which define each of the levels are presented as a flow diagram, Figure 5. Requirements for lower level information develop when the above status indications show degradation of capabilities. The lower levels of information are discussed in the following paragraphs.

Figure 4.

Hierarchical Information Flow
For Communications Systems.



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Maintenance and Supervisory Technicians Require Test Measurement Information	Same

Figure 5.

M1→M4 Decision Flow Diagram

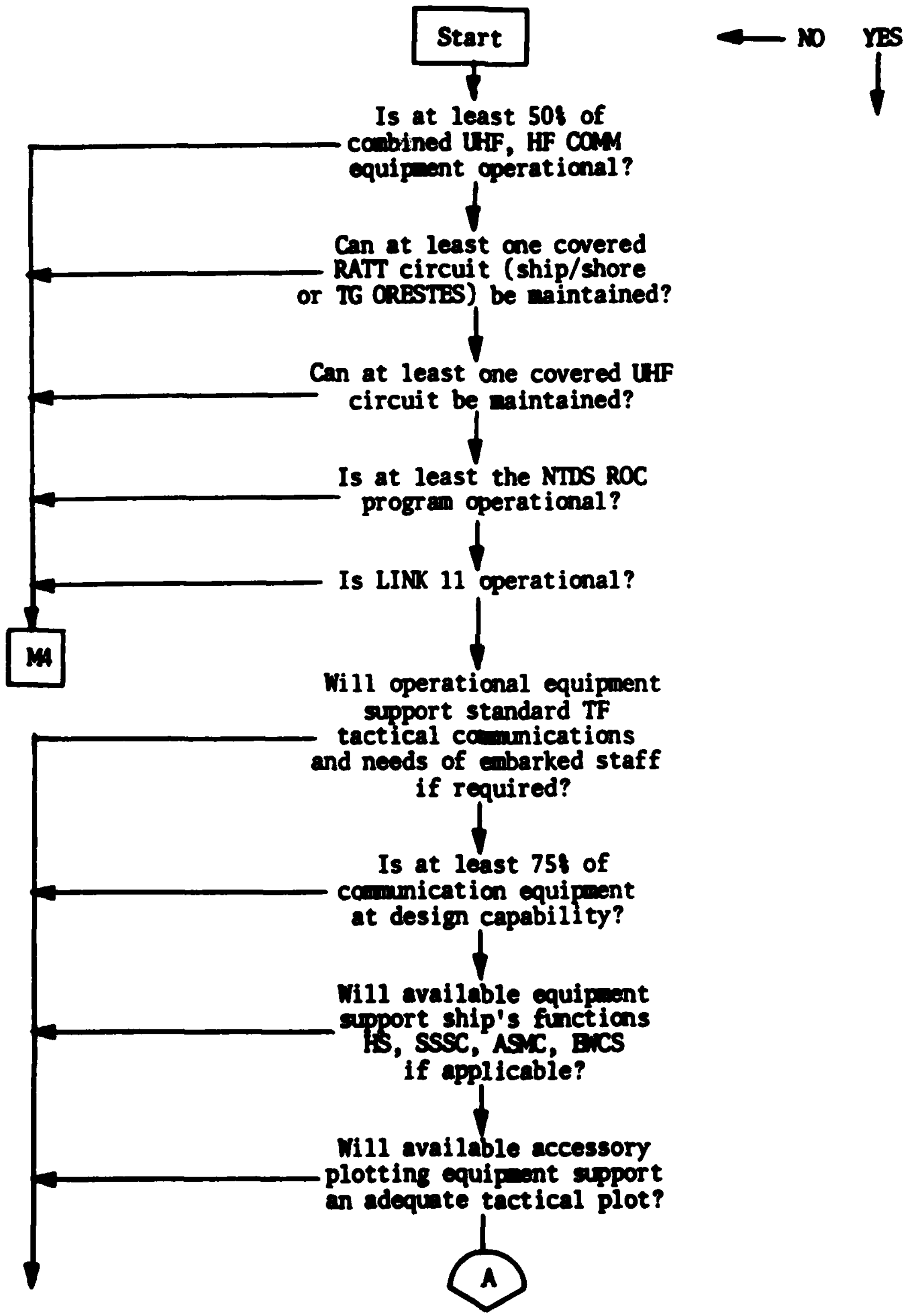
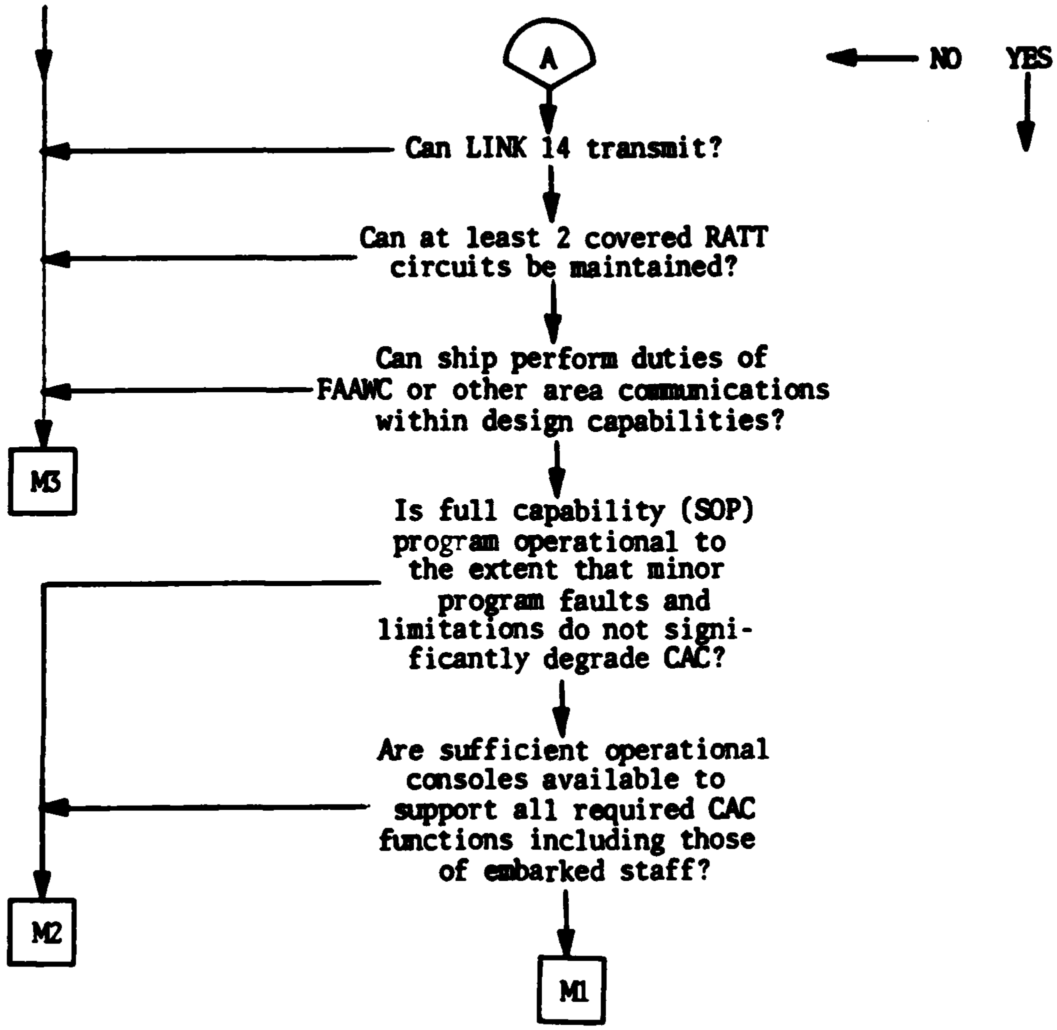


Figure 5 (cont.)



c. Operations requirements.

The Operations level is an intermediate level more related to Command than to Maintenance. Original designers of the monitoring system had not considered the level directly; rather, they had supposed the technician's watch supervisors (thought to be Communications Officers) to be an intermediate level for the flow of information. Reference 6 shows that while the idea is correct, the essentials are missing and the flow is from Communications Officer to Operations Officer to Commanding Officer (Fig. 4). The Communications Officer is a member of the first level (equipment level).

The highest level of system status information required at the Operations level (Operations Officer) is defined as C1 through C4. Each major equipment group will have a definitive set of considerations which indicate the level of operability (C1 - C4) for the equipment group. Thus, HF communications will have one, Satellite communications (SATCOM) will have another, UHF communications will have still another, and so forth. The monitor system under study herein has BSI units for HF and UHF communications, and the criteria for establishing conditions C1 - C4 for them is classified, but can be found in COMNAVSURFPACINST 3501.3, Readiness Reporting Guide (Ref. 12).

d. Maintenance requirements.

The maintenance level (equipment level) is the lowest level in the hierarchy and requires the most detailed technical information. Technicians are required to perform a variety of measurements, usually on a periodic basis, which are designed to ensure equipment operability. The system in use is the Planned Maintenance System (PMS) and the information required by technicians is delineated by Maintenance Requirement Cards (MRC) (Ref. 5). An example MRC is reproduced as Figure 6. This card is one of a group related to PMS on HF receivers and indicates three tests which are

Figure 6.

Maintenance Requirement Card for HF Receiver Sensitivity Test

SHIP SYSTEM	SUBSYSTEM	MRC CODE	
Combat		C-193 W-1	
SYSTEM	**EQUIPMENT**	**RATES**	**M/H**
	AN/SRC-20,20A Radio Set	RM3	0.4

MAINTENANCE REQUIREMENT DESCRIPTION

1. Test operate radio set.

SAFETY PRECAUTIONS

1. Forces afloat comply with Navy Safety Precautions for Forces Afloat, OPNAVINST 5100 series.

TOTAL M/H 0.4

ELAPSED TIME 0.4

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Handset
2. Dummy Load, DA-412/U (SCAT 4683)
3. Test cable, RG-213/U with type C male connector on one end and type N male connector on other end

PROCEDURE

Preliminary

a. Set RF Amplifier AM-1565/URC switches and controls:
   (1) TEST KEY to OFF
   (2) EXCITATION to AUTO
   (3) LOCAL-REMOTE to LOCAL
   (4) RF POWER OUTPUT to *HIGH*
   (5) POWER to POWER
b. Set AN/URC-9( ) switches and controls:
   (1) CHAN SEL to REMOTE PRESET
   (2) MODE to TONE
   (3) SQUELCH to OFF
   (4) Power to ON
   (5) DIMMER fully clockwise
c. Set Radio Set Control C-3866/SRC switches and controls:
   (1) EMERGENCY POWER to POWER
   (2) LOCAL-REMOTE to LOCAL
d. Disconnect antenna cable from RF amplifier ANT jack.
e. Connect dummy load to RF amplifier ANT jack.
f. Connect handset to AN/URC-9.

1. **Test Operate Radio Set.**
   a. Momentarily press RADIO SET POWER START button; POWER indicators on radio set control, RF amplifier and AN/URC-9( ) should light; EMERGENCY POWER indicator lamp on radio set control should light.
   b. Allow a 5-minute warmup.
   c. Set AN/URC-9( ) METER switch successively to the following positions; meter should indicate NORMAL at each position.
      (1) +325V
      (2) +125V

PAGE 1 OF 3

C6

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MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4700 - 1 ( ) (REV)

performed by the technician. The test made by the BSI effectively makes the three tests in one measurement, under controlled conditions, called "noise figure test." This measurement is also displayed as "receiver sensitivity."

e. Monitor system operators.

The LAT and BSI units of the monitor system will be operated by technicians from maintenance divisions (ET rate, electronic technician). The BSI will be operated by ET2 or ET3 level personnel, and the LAT, a supervisory position, will be operated by ET1 or ETC. The refined information, status, estimated time to repair, supply status, etc., will be forwarded to the Command Reporting System. The Communications Officer or Electronics Material Officer, as an organizational supervisor, is likely to make use of the LAT in the case of a less than perfect system status indication (C2 through C4). The Operations or Combat System Officer and the Commanding Officer, which represent the next two higher levels of information flow, will be primary users of the Command Reporting System (CRS).

2. Control and display design.

a. LAT design.

The basic functions performed at the LAT are:

(1) Acquire and maintain information on the status of all BSI units connected to it.

(2) Assign tasks for maintenance of these BSI units and supervise the task performance.

(3) Report status information to Command personnel.

Performance of the functions requires the completion of various tasks, some of which will be accomplished by equipment and others by personnel. The design for the LAT controls and displays depends on which tasks will be allocated to

operators and which to equipment. This allocation is based upon a consideration of which types of things are done best by people and which by machines, and is a major input to the system design. The system design will determine the man-to-man, man-to-machine, and machine-to-machine interfaces. A block diagram showing these interfaces for the monitoring system is provided in Figure 7. The specific tasks to be performed at the LAT are listed in Table 2.

A design for the LAT controls and displays has been completed. The design consists of a cathode-ray-tube (CRT) display device and an eight-button function key control device. These are shown in Figure 8. Design of the keyboard for alphanumeric entry of information about supply status, operational capabilities (Fig. 5), or problems associated with repairing equipment is beyond the scope of this project.

The specific control actions that the LAT operator would need to take were determined and grouped into ten sets of eight or fewer actions per set. This grouping enables the control devices to be a simple bank of eight function keys. These keys will be positioned directly below a CRT that will display the LAT information. The CRT display is divided into three areas as shown in Figure 8. The functions to be performed when the operator presses a function key will depend on the selected function key action set. The LAT action set display shown in Figure 8 is divided into eight sections located directly above the eight keys. Each section indicates the function which will be performed when the corresponding key is pressed. The formats for this display are shown in Figure 9. The top portion of the CRT display shows the current overall status of the Base System equipment and the current status of the monitoring system. These displays provide a quick overview of the current situation and are continually updated to present the most current

Figure 7.

Block Diagram of Monitor System Interfaces

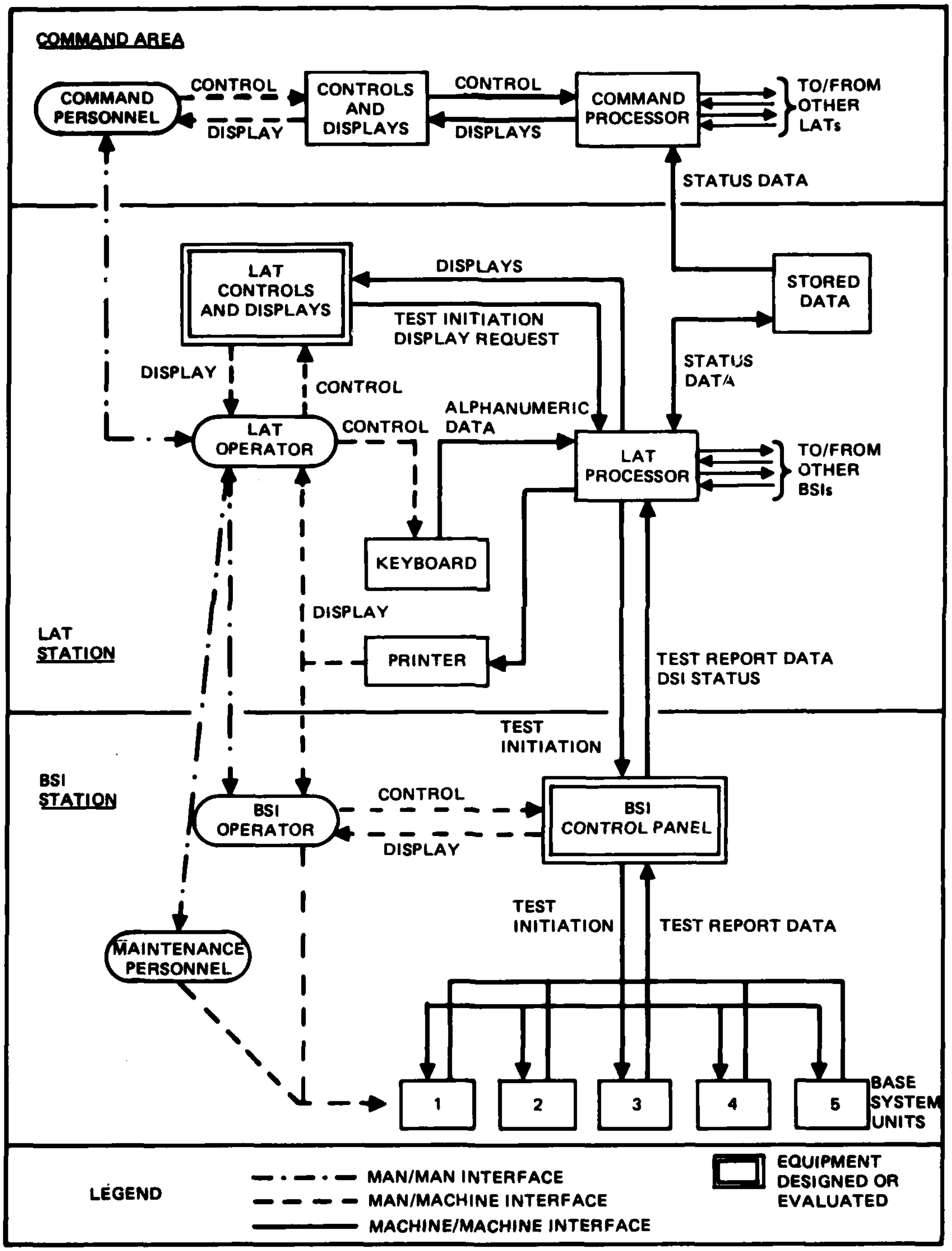


Table 2.
LAT Task Allocation

No	Task Description	Allocated To
1	Initiate tests to obtain BSI unit status data and data on the performance of the monitor system	a) Equipment, to accomplish automatically when first starting the monitor action and periodically thereafter b) Operator, to accomplish when needed due to a particular situation
2	Establish the rate of periodical automatic status testing	Operator
3	Direct BSI Station Equipment to perform unit testing	Equipment
4	Receive BSI unit status Information from BSIs	Equipment
5	Maintain records of BSI unit status data	Equipment
6	Determine what testing to perform in special situations	Operator
7	Provide information to the operator for evaluation and decision making	Equipment
8	Provide status information to command personnel	a) Equipment, for information received from BSIs or entered into storage by keyboard b) Operator, for evaluations and estimates not part of stored data

Table 2. (cont.)

9	Respond to directions from command personnel	Operator
10	Keep informed about BSI unit status to enable making maintenance decisions	Operator
11	Direct maintenance personnel to perform specific tasks	Operator
12	Obtain and evaluate informal information from maintenance personnel	Operator
13	Supervise performance of maintenance personnel	Operator

Figure 8.
LAT Display and Control Console

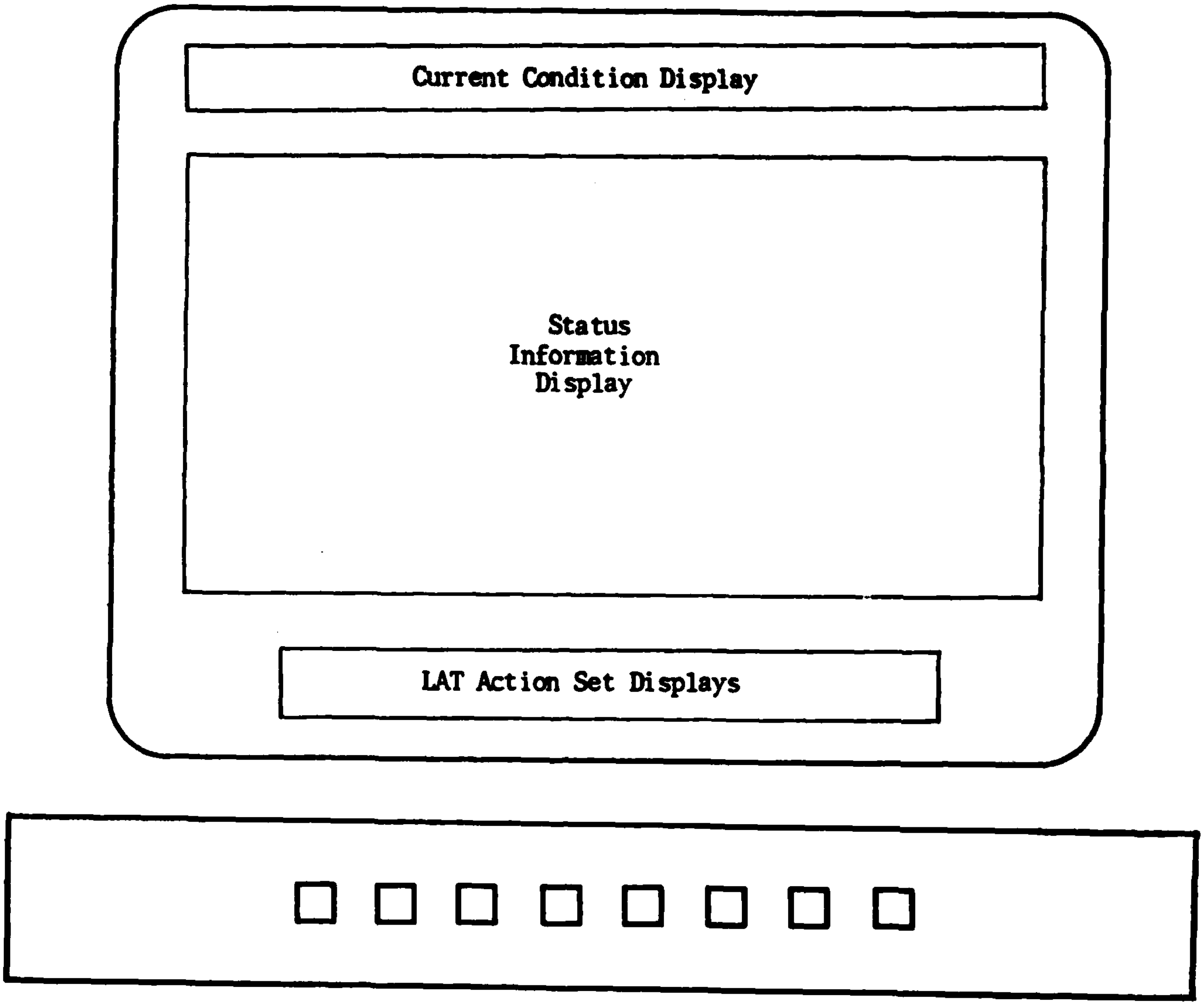


Figure 9.
LAT Action Set Displays

Performance Checks on Monitor System Operation							
NEXT SET	LAT SELF	BSI 1 INTER	BSI 1 SELF	BSI 2 INTER	BSI 2 SELF	BSI 3 INTER	BSI 3 SELF

Change Time For Periodic Unit Testing							
NEXT SET	NORMAL PERIOD	BSI 1 30 MIN	BSI 1 1 HR	BSI 2 30 MIN	BSI 2 1 HR	BSI 3 30 MIN	BSI 3 1 HR

Initiate BSI 1 R-1051 Tests							
NEXT SET	R-1051 (1)	R-1051 (2)	R-1051 (3)	R-1051 (4)	R-1051 (5)	R-1051 (6)	R-1051 (7)

Initiate BSI 2 SRC-20(N) Tests							
NEXT SET	ALL SRC-20		ALL TESTS	RCVR SENS	POWER OUTPUT	MODU-LATION	VSWR

Obtain Summary Status Displays							
NEXT SET	ALL UNITS		PROBLEM UNITS		UPDATE NEEDED	LOCKED OUT	HARD COPY

Obtain BSI Unit Test Reports							
NEXT SET	BSI 1 UNITS		BSI 2 UNITS		BSI 3 UNITS		HARD COPY

information. They are presented at the top of the display area and separated from the other display information so that they will stand out, since they alert the LAT operator to situations which may need his special attention. None of the alerts were so time critical as to warrant the use of flashing lights or audio signals. A proposed format for this display is shown in Figure 10. The group at the left of this display shows the most critical factors about the monitored equipment. The overall condition code (C1, C2, C3, C4) indicates the level of capability of the monitored equipment. The other two status items are simply the number of Base Equipment units that are experiencing problems (failures, no status information available, etc.) and the number of units for which updated status information is needed shortly or the units will be considered problem units. The group at the right of the display indicates whether the different monitor system performance areas are OK or BAD. These indicators were chosen rather than others such as GO and NO-GO which would infer that the indicated status pertains to the ships operational condition. The status indicated by OK or BAD is simply whether the monitor system is operating correctly, not whether the operational equipment is operating correctly.

Descriptions of other displays that will be presented to the operator are provided in Appendix B.

b. BSI (R-1051).

The existing design for the BSI (R-1051) control panel (Figure 11) has been evaluated. Several changes are suggested in order to improve the design from the human factors aspect. The changes are shown in Figure 12, and are discussed below:

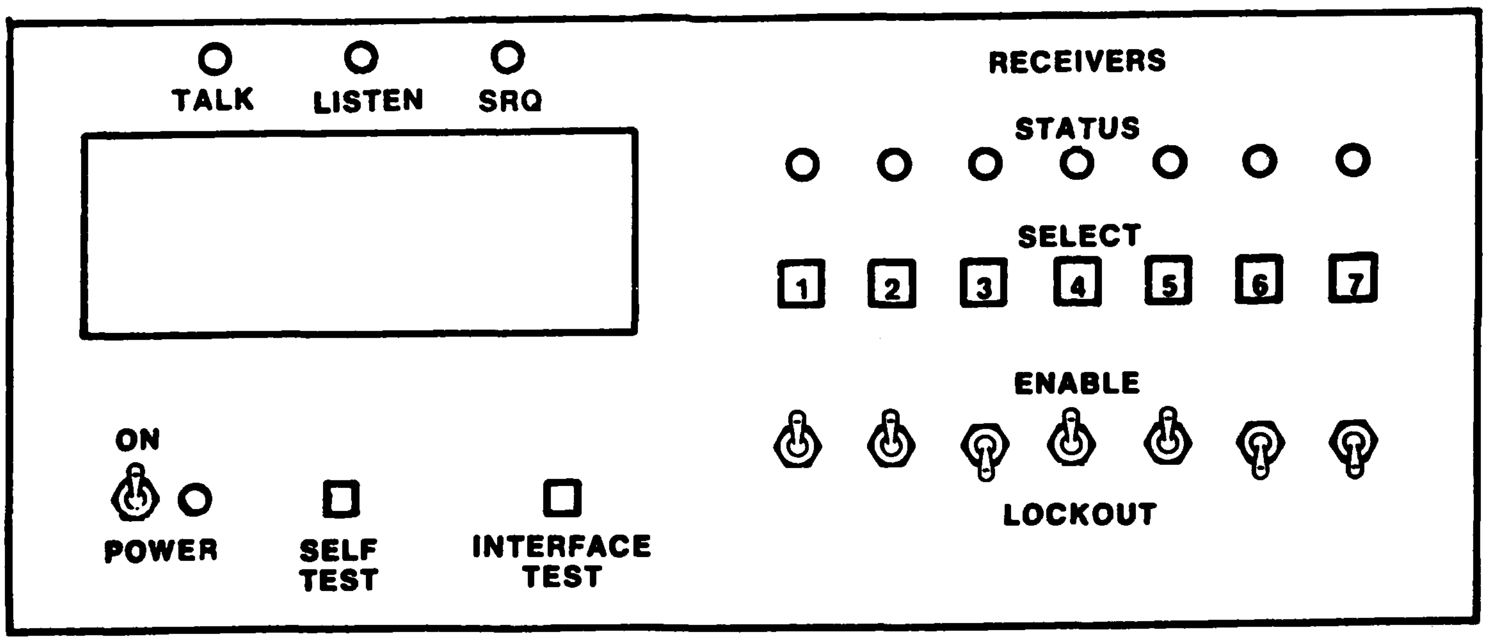
Figure 10.
Current Condition Display

OVERALL CONDITION	PROBLEM UNITS	REQ UPDATE
C-2	4	3

LAT STATUS	BSI 1		BSI 2		BSI 3	
	INTFC	SELF	INTFC	SELF	INTFC	SELF
OK	OK	OK	OK	OK	BAD	BAD

Figure 11.

Evaluated Design for Panel of
BSI for R-1051



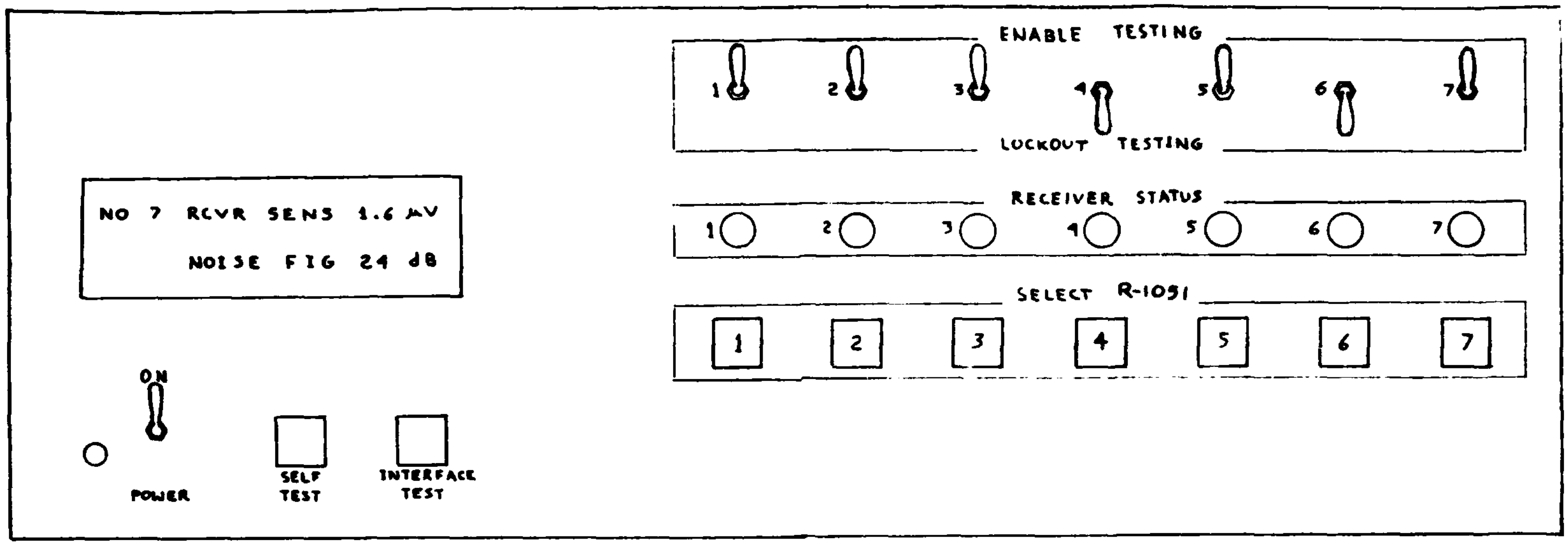


Figure 12.

Proposed Redesign for Panel of BSI for R-1051

(1) Remove the TALK, LISTEN, and SRQ display lights since they do not present information pertinent to the operation of the panel or results of the testing.

(2) Relocate the ENABLE, LOCKOUT toggle switches to the top of the panel so that the operator's hand does not obstruct his view of these switches while he is selecting the unit to be tested. This relocation places the indication of whether or not testing of a unit is "locked out" near the status light for that unit. If the operator inadvertently attempts to test a "locked out" unit and sees no indiction of the test results on the status light, he will easily notice that testing is "locked out".

(3) Keep the functional grouping of control and displays, but clearly indicate the functional boundaries and provide more precise labels for the functional areas.

(4) Provide a number label for each toggle switch and status light to indicate with which receiver they are associated. Furthermore, although it cannot be done on the panel, the operator must be provided with information to determine which actual physical unit corresponds to receiver number 1, 2, 3, etc.

(5) Place labels indicating particular tests to be performed on the test control pushbuttons where possible.

(6) Provide standardization among BSIs of control and display positioning.

(7) Provide 1.25" instead of 1.00" separation between the centers of the toggle switches, status indicator lights and unit selector push buttons. This will reduce the risk of inadvertently bumping and possibly actuating an adjacent control. The separation distances are slightly above the recommended minimums in McCormick (Ref. 7), Figure 11-14.

(8) Specify that toggle switches are 1/8 inch wide at the tip, 0.7 inches long, and require a displacement of 50 degrees and force of 20 oz to operate, pushbuttons are 0.5 inches square and require a displacement of 3/16 inch and a force of 20 oz to activate. These characteristics meet the requirements of McCormick (Ref. 7) Appendix B, Table B-2.

(9) Place the POWER ON indicator light to the left of the power on/off switch so that it is not associated with the SELF TEST pushbutton.

(10) Specify that status lights are three-color; red for failure, yellow for pass but marginal, and green for good, and that the lights are 3/8 inch in diameter.

(11) Reduce abbreviations to a minimum and use abbreviations in accordance with MIL-STD-12C.

The use and lighting conditions which are relevant to the panel design are listed below:

(1) The panel will be in a standard equipment rack in a shipboard equipment area.

(2) Operators will be trained maintenance technicians meeting physical and mental requirements for Navy enlisted personnel.

(3) The mid-point of the panel will be between 44 and 54 inches from the floor.

(4) Operators may be required to write test results' numerical values on blank forms. Therefore, the measured values, such as power output, will be displayed for at least 15 seconds. When a test is inadvertently attempted on a unit that has testing locked out, the test result readout will be of the form "NO. 3 LOCKED OUT" so feedback to the operator is always provided.

(5) Operators will operate the panel from a distance no greater than arm's reach (approximately 20 inches).

(6) Room lighting will be the normal shipboard equipment area white lights. Panel illumination will be above 1 ft-L.

(7) Panel surfaces will have a flat finish to reduce glare.

(8) The normal sequence of operations is as follows:

a. Set the toggle switches to ENABLE or LOCKOUT testing.

b. Perform "self test" and "interface test." Check the readout after each test.

c. Select the test(s) to be performed (BSI SRC-20 only).

d. Select the unit(s) to be tested.

e. Check the unit status (status lights).

f. If the status light does not light, check the toggle switch setting to see if testing of that unit has been locked out.

g. If the status light is not green, record the reported value on the appropriate form.

h. If more than one test and/or more than one unit has been selected, repeat items e, f, and g.

i. When additional testing is required, repeat items c through h.

Specific characteristics of the test results readout are as follows:

(1) The readout will be constructed from ten Hewlett-Packard four-character solid state alphanumeric display components. These components will be arranged to provide two rows of 20 characters as shown in Figure 12. The characters are formed with a 5 by 7 dot matrix using light-emitting diodes (LED's).

(2) The width and height of capital letters and numbers are 0.105 and 0.146 inches respectively except for the letter I and number 1. I and 1 are both 0.063 by 0.146 inches.

(3) The color of the characters is red.

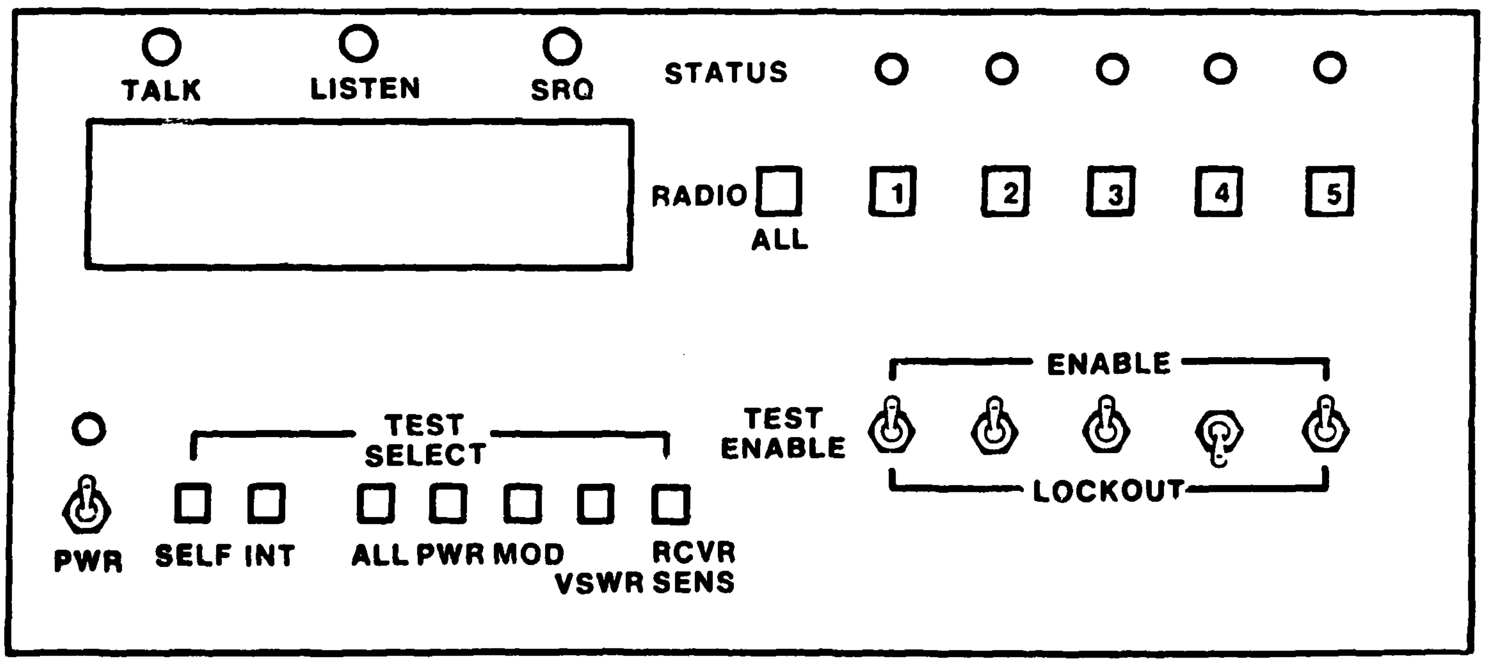
(4) Additional information, including the configuration of all 128 characters, is provided in Appendix C. This readout has been operated and informally evaluated by various subjects. Their subjective feelings are that the characters are very readable at the distances occurring in normal operation. When asked to estimate the height of the characters, most subjects reply with a value of approximately 1/4 inch rather than the actual height (0.146 inches). Also, the sample readout shown in Figure 12 is actual size and these characters seem to be quite readable from 20 inches. Furthermore, the character heights meet the requirement of 0.090 inches for a viewing distance of 20 inches or less, with an illumination level above 1 ft-L as specified in MIL-STD-1472B, paragraph 5.5.5.13. Experiments could be conducted relatively easily and would determine if the readouts are indeed acceptable. It is suggested that a group of 15 to 20 subjects be tested to determine the accuracy with which the readout can be read at 20 and at 30 inches. An error would consist of perceiving a wrong unit number, measured parameter (modulation etc.), or reported value (24 dB, etc.). A criterion of acceptable percentage of errors would have to be established based on the criticality of making an error. If the results prove to be inconclusive, further testing could be performed.

c. BSI (SRC-20).

The existing design for the BSI (SRC-20) control panel, presented in Figure 13, has been evaluated. As with the other BSI control panel, several changes are suggested. The changes are incorporated into the proposed panel design shown in Figure 14. Most of the changes are the same as those proposed for the BSI (R-1051). The use and lighting conditions for both BSI's will be the same, and the proposed designs are nearly the same.

Figure 13.

Evaluated Design for Panel of
BSI for SRC-20



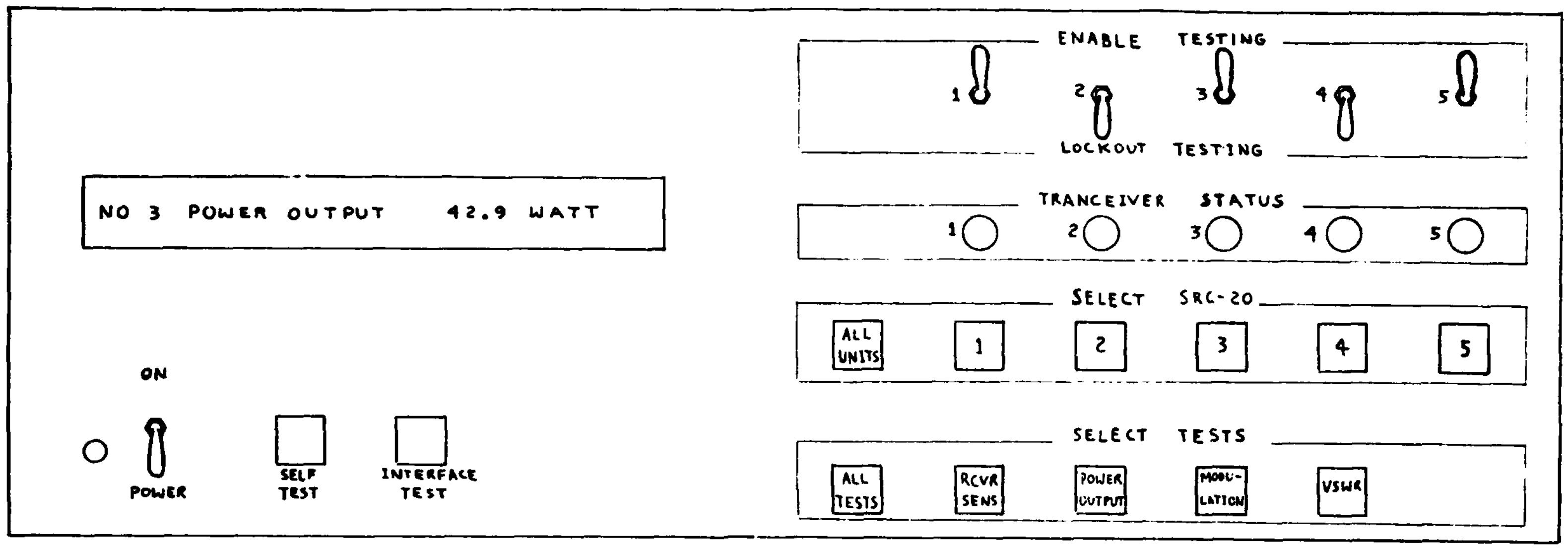


Figure 14.

Proposed Redesign for Panel of
BSI for SRC-20

There are three differences in the designs. First, the test results readout will be one row with 32 characters, and it will display the measured value of a given parameter for a specific unit. Second, there are only 5 different units to be tested. The third difference results from the fact that the operator can elect to run any combination (or all) of four different tests on a specific unit or on all units. This capability is provided by adding a set of pushbuttons to select the test(s) as shown in Figure 14, and by including a pushbutton to select all units.

The layouts of the controls and displays for the proposed designs of both BSI panels are based on the sequence of operations described in paragraph 2.b BSI (R-1051). The primary considerations for the layouts are to arrange controls and displays to:

(1) Minimize the lengths of links that are most frequently used by considering the normal operational sequence.

(2) Minimize the interference between operating the controls and viewing the displays.

(3) Maximize the standardization of panel layouts.

(4) Group controls and displays according to functions.

(5) Maximize simplicity of the layout.

The panel labeling is shown in actual size in Figures 12 and 14. The minimum character height is 0.12 inches, and as stated in paragraph III 2.b, the panel illumination will be above 1 ft-L. This size meets the requirements as specified in MIL-STD-1472B, Table X for noncritical identification labels. To assure that the other requirements of MIL-STD-1472B have been met by the controls and displays of the LAT and both BSI's, a check-off list has been completed. This list is shown in Appendix D. For the most part, abbreviations have been avoided in both the panel labeling and display

readout. The abbreviations used are listed below, and are in accordance with MIL-STD-12C (applicable pages shown in Appendix E).

Labels	RCVR	for receiver
	SENS	for sensitivity
	VSWR	for voltage standing wave ratio
Readout	NO	for number
Display	FIG	for figure

Some other abreviations may be used for parameter units, such as dB for decibel or μV for microvolt, but these will always be standard technical abbreviations. All abbreviations will be completely defined in users' manuals and training materials.

IV. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions.

a. User requirements.

The requirements for system status and technical information by the various organizational levels of Navy ship's crews are established by official instruction, operational activity (mission), operational readiness, individual preferences, and other factors. Each of these usually interacts with some or all of the others, as indicated in Section III.

Some of the information is defined in detail, some is highly technical and some extremely tedious. The proposed Shipboard Monitoring System appears to

have a potentially significant role in the streamlining of information flow and the relief of some of the tedium.

b. Controls and displays.

Two operator control panels (for BSI units) were evaluated for human factors and a third was designed for the first time (LAT). The evaluated units were found to have a few undesirable aspects and were redesigned with improvements. The LAT control panel design is proposed to the system designers to be included in their laboratory model of the monitoring system.

2. Recommendations.

a. User requirements study.

The large variability of the kinds and distribution of system status information, as suggested above, indicates a need for system designers to incorporate a thorough investigation into the subject. The needs of the Navy shipboard organization are documented, and the personnel are willing to indicate problems and areas of difficulty in existing systems.

It is recommended that the designers of the Shipboard Monitoring System:

(1) Research the subject of information flow, as suggested in this report, to clarify their concepts of the utilization of such systems.

(2) Identify existing systems which will be impacted by the development of such a system (e.g. NAVFORSTAT, PMS, etc.) for the purposes of solving old problems and avoiding the creating of new problems for shipboard personnel.

b. Controls and displays.

The redesigned BSI control panels, and the proposed design for the LAT control panel have been described in Section III, paragraph 2. The recommendation is that the system designers use these panels for their laboratory model.

As continued investigation into the human factors of the Shipboard Monitoring System design, three types of experiments and testing of components are suggested:

(1) Readout devices (BSI).

Several types of alphanumeric readout devices are available which would perform the required display function for the BSI. Among these are units using the following listed technologies:

(a) light emitting diodes (LED)

(b) plasma discharge displays

(c) liquid crystal

(d) vacuum fluorescent

Because some of these technologies have been introduced recently and are still being developed and changed, useful human factors information which could be used in the selection of a particular display unit for the BSI is not readily available. For this reason a series of tests should be conducted to aid in this selection process using subjects which match characteristics of potential users. Candidate display units should be selected and operated in environments which approximate those in which the various BSI units will be operating aboard ship. Tests should then be conducted to determine if a single display type can be selected to function optimally in all anticipated environments. In addition, special tests may be required to fully evaluate each display type. For example, Riley (Ref. 13) reports that multiple imaging as a function of vibration and refresh rates can occur. No investigation or testing was done on this subject, but such effort is recommended because of

known vibration problems aboard Navy ships.

(2) Variable function keys (LAT).

Operator entry to the LAT is by means of the eight button function key control device shown in Figure 8. The function of a particular key is determined and controlled by the LAT as a function of system operation. Labels for the function keys are located immediately above the buttons on the CRT display device. Tests should be conducted to:

(a) evaluate the use of variable function keys vs a much larger number of dedicated function keys.

(b) determine the optimum location and orientation of the function keys relative to the location of the labels on the CRT device.

(c) determine the optimum location and character font for the key labels for avoiding confusion with other LAT display information.

(3) System level testing and evaluation.

Testing and evaluation (T and E) of the monitor system will consist of the following parts:

(a) Laboratory testing and redesign of breadboard unit by design engineers

(b) Shipboard testing of advanced development model conducted by system designers with assistance of ship's personnel

(c) Shipboard testing of engineering development model conducted by Navy testing organization (OPTEVFOR). Each stage of testing must be concerned with testing, evaluating, and optimizing human factors aspects of the design and application of the monitor system, in order to ensure a suitable development.

APPENDIX A

User Requirements.

The typical Commanding Officer of a U. S. Navy ship wants to know as much as possible about the status of his ship even though he may not ultimately understand or "need to know" all the information he requests. This is partly because he is completely responsible for the ship, its equipment, and the lives of all personnel on board, and partly because of the inquisitiveness of the human being. However, the information required by Command level personnel, such as the Commanding Officer and Department Heads, differs in content and format from that required by shipboard maintenance personnel.

The maintenance information initially comes from the BSI and is directly usable only in conjunction with the applicable MRC (Maintenance Requirement Card) and Technical Manual. This data need only go as far as the LAT with the provision that it be stored for a specified period of time. Additional data must be already stored in the LAT in the form of subroutines or can be key entered by the operator. The amount of information presented at the CRS (Command Reporting System) is subject to close scruitiny, for if the system does not circumvent today's communications problems within the ship's chain of command it is useless at best. Since the information at the BSI and LAT is already delineated, it remains only to look at the CRS organization for information content.

The information presented and gathered should be, if possible, mostly from reporting systems that already exist. This is possible because the Navy has well-defined information systems in use and it remains only to automate this information, since it is familiar to everyone in the chain of command.

The information needed at the highest levels of Command and Control is

presented in the NAVFORSTAT CASREP System and PMS/MDS Systems. The Casualty Report (CASREP) is the expeditious means of reporting the status of a ship experiencing a diminished combat readiness posture. It serves to advise the operational chain of command of personnel and/or equipment/material conditions limiting operational readiness and also alerts logistical commands to the situation. CASREPS are not a substitute for, but are in addition to, and complement the 3-M (PMS and MDS) data. Because of the timeliness of CASREP information it is used in conjunction with NAVFORSTAT data to evaluate the combat readiness of Naval forces. It further alerts maintenance and material managers to significant problems and thus not only initiates the actions necessary to resolve the immediate casualty but also promotes detailed analysis of 3-M and related data in an effort to prevent recurrence. Regular 3-M reports are required even though CASREPS have been submitted. Since a CASREP reports only the casualty status of equipment/material, it is not a substitute for reporting in the NAVFORSTAT system. CASREPS are coded using the readiness rating codes of C2, C3, and C4 which have as a basis the mission area M1, M2, M3, and M4 ratings in the NAVFORSTAT. The 2-Kilo (Figure A-1) and 1250 (Figure A-2) forms are also tied into this system. The ship's maintenance action form (2-Kilo) is utilized as a request and documentation form for ship's force or shore based maintenance. The 1250 document lists information required to requisition a part from the supply system.

All of these reporting/documentation systems utilize the same basic information and therefore lend themselves to use in the Command Reporting System.

The first level of reporting comes from the "M" readiness ratings of the NAVFORSTAT. This details the overall readiness according to a general breakdown of ship mission areas. Command Control and Communications (CCC)

OPNAV 4790/2K (Rev. 0-78) S/N 0107-LF-047-8811

SHIP'S MAINTENANCE ACTION FORM (2-KILO)

COMP DEFL

SECTION I. IDENTIFICATION

JOB CONTROL NUMBER

1. SHIP'S UIC | 2. WORK CENTER | 3. JOB SEQ. NO. | 4. APL/AEL

A. SHIP'S NAME | 5. EQUIPMENT NOUN NAME | 6. WHO | 7. STA | 8. CAS | 9. DFR | 10. | 11. | 12.

B. HULL NUMBER | 13. IDENT. EQUIPMENT SERIAL NUMBER | 14. EIC

15. SAFETY HAZARD | 16. LOCATION (Compartment Deck Frame Side) | 17. WHEN DISCOVERED DATE YR DAY

CONFIGURATION CHANGE | FOR INSURV USE

18. ALTERATIONS (SHIPALT, ORDALT, Fld Chg, etc.) | 19. | 20. INSURV NUMBER | 21. | 22. | 23. S | 24. P/T

SECTION II. DEFERRAL ACTION

25. S/F MHRS. EXP. | 26. DEFER. DATE | 27. | 28. DEADLINE DATE YR. DAY

SECTION III. COMPLETED ACTION

FOR SELECTED EQUIPMENTS ONLY

30. | 31. COMPLETION DATE YR. DAY | 32. METER TIME | 33. | 34. METER READING

SECTION IV. REMARKS/DESCRIPTION

35. REMARKS/DESCRIPTION

36. CONT. SHEET

37. CSMP SUMMARY

38. FIRST CONTACT MAINT. MAN (Print) | 39. | 40. | 41. | 42. | 43. PRIORITY

SCREENING

C. DIV. INIT. | D. DEPT. INIT. | E. | F. AUTHORIZATION | 44. IUC | 45. TYCOM

46. SPECIAL PURPOSE | A. | B. | C. | D. | E. | F. | G. | H. | I. | J. | K. | L.

SECTION V. SUPPLEMENTARY INFORMATION

47. BLUEPRINTS, TECH. MANUALS, PLANS, ETC. | AVAILABLE ON BOARD YES NO | 48. PREARRIVAL ARRIVAL CONFERENCE ACTION/REMARKS

SECTION VI. REPAIR ACTIVITY PLANNING/ACTION

49. REPAIR W/C | 50. EST. MHRS. | 51. ASST. REPAIR W/C | 52. ASST. EST. MHRS. | 53. SCHED. START DATE YR DAY | 54. SCHED. COMP. DATE YR DAY

55. REPAIR ACTIVITY UIC | 56. WORK REQ. ROUTINE | 57. EST. MANDAYS | 58. EST. MANDAY COST $ | 59. EST. MATERIAL COSTS $

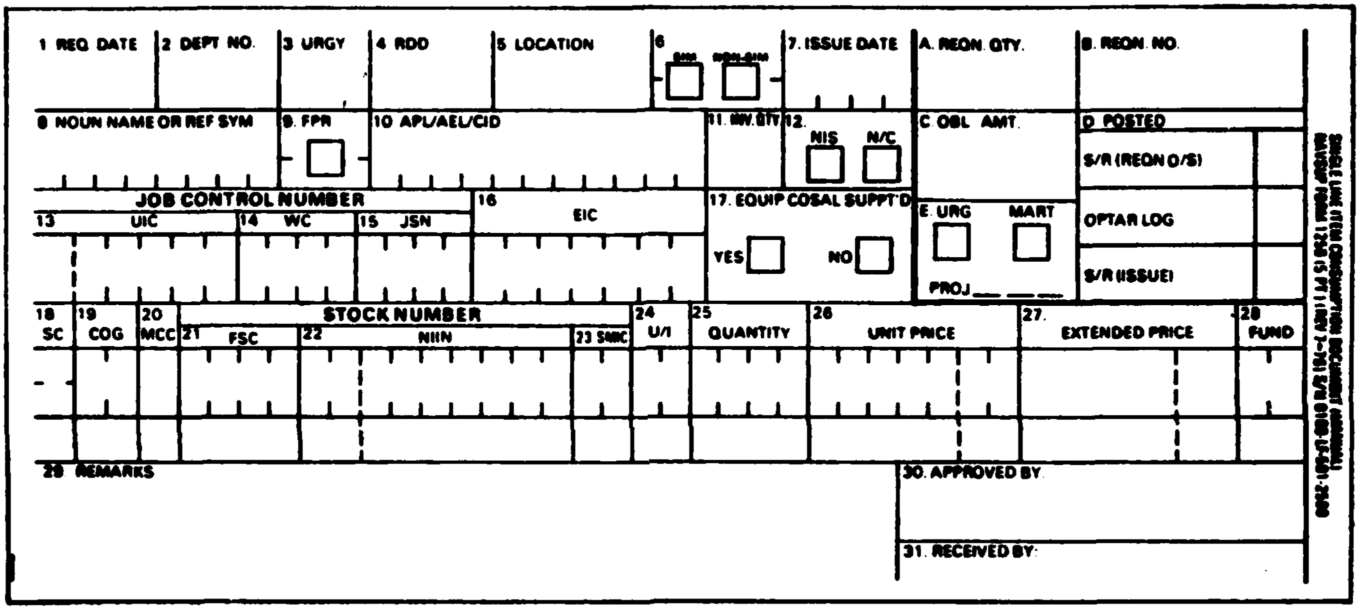
60. EST. TOTAL COST $ | 61. JOB ORDER NUMBER | 62. LEAD PSE CODE | 63. DATE OF EST. YR DAY

64. FINAL ACT. | 65. MHRS. EXPENDED | 66. DATE COMPLETED YR DAY | G. COMPLETED BY (Signature - Rate) | H. ACCEPTED BY (Signature - Rate/Rank)

☆U.S. GOVERNMENT PRINTING OFFICE: 1978-724-317

Figure A-2

Example Form: NAVSUP 1250


1 REQ DATE
2 DEPT NO.
3 URGY
4 RDD
5 LOCATION
6
7. ISSUE DATE
A. REQN. QTY.
B. REQN. NO.
8 NOUN NAME OR REF SYM
9. FPR
10 APL/AEL/CID
11. INV. QTY
12.
NIS
N/C
C. OBL AMT.
D. POSTED
S/R (REQN O/S)
JOB CONTROL NUMBER
13 UIC
14 WC
15 JSN
16 EIC
17. EQUIP COSAL SUPPT'D
YES
NO
E. URG
MART
PROJ
OPTAR LOG
S/R (ISSUE)
18 SC
19 COG
20 MCC
STOCK NUMBER
21 FSC
22 NIIN
23 SMIC
24 U/I
25 QUANTITY
26 UNIT PRICE
27. EXTENDED PRICE
28 FUND
29 REMARKS
30. APPROVED BY
31. RECEIVED BY
SINGLE LINE ITEM CONSUMPTION DOCUMENT (MANUAL)

covers the entire spectrum of equipment and is adequate for initial reporting. The criteria for determining the rating are found in Figure 5. Additional criteria are classified but can be found as referenced in Table A-1. Information key-entered and retrieved from storage at the LAT, Table A-2, can be used to print out documents 2-Kilo, 1250 and CASREP messages with minimum operator interface. Subroutines can be developed to provide this information by the use of a simple matrix, LAT operator interface and the maintenance information generated at the BSI, Table A-3. This level of information is of little consequence to Command and it is used for indication of equipment performance and proper selection of the PMS (Planned Maintenance System) MRC (Maintenance Requirement Card) and technical manual for trouble-shooting the inoperative equipment.

Table A-1
Command Reporting System Data

1.0 Mission Area Status (Ref. 6, Ref. 12)
1.1 Mission Area Subsystem Status (Ref. 6, Ref. 12)
1.2 Capability Degraded, That Subsystem
1.3 Equipment Degraded
1.4 Estimated Time to Repair
1.5 Parts Status (if required)

Table A-2
Local Area Terminal Data

2.0 Data keyed by operator and/or retrieved from storage to fill out OPNAV 4790/2-K Fig A-1, NAVSUP form 1250 Fig. A-2, and CASREP Message (Classfied)

Table A-3
Base System Interface Data

R-1051

3.0 Noise Figure

SRC-20

4.0 VSWR
4.1 Output Power
4.2 Modulation
4.3 Receiver Sensitivity

Appendix B

The center area of the LAT CRT will display various tables which provide status information. This information may be general or detailed, and refer to the overall status of the equipment or a specific parameter of a particular unit. The displays must provide operators with information that is meaningful and helpful for performing their tasks. Figures B-1 through B-5 show a first cut at the display designs.

Operators will be provided with training and manuals to assist them in reading these displays. However, care has been taken to make the displays as clear and direct as possible. It is expected that some LATs will control three BSIs and so the designs make provisions for a third BSI. The actual tables presented at a LAT will only show BSIs that are controlled by that LAT.

The test report for units monitored by BSI 2 is shown in Figure B-5. Similar test reports will be provided for the units monitored by other BSIs.

DISPLAY AREA

STATUS SUMMARY OVERALL = C2 BSI 1 = C2 BSI 2 = C1 BSI 3 =

BSI 1 UNITS	GOOD	PASS	FAIL	NONE
R-1051 (1)	X			
R-1051 (2)		X		
R-1051 (3)	X			
R-1051 (4)				X
R-1051 (5)			X	
R-1051 (6)				
R-1051 (7)	X			

BSI 2 UNITS	GOOD	PASS	FAIL	NONE
SRC-20 (1)		X		
SRC-20 (2)		X		
SRC-20 (3)	X			
SRC-20 (4)	X			
SRC-20 (5)				X

BSI 3	GOOD	PASS	FAIL	NONE

NONE INDICATES TESTING NOT PERFORMED OR TEST RESULTS OUTDATED

NOTE: THIS TABLE IS DISPLAYED WHEN THE OPERATOR PRESSES THE ALL UNITS FUNCTION KEY

FIGURE B-1 OVERALL STATUS SUMMARY

DISPLAY AREA

BSI 1 UNIT PROBLEMS							
	R-1051 NO						
PROBLEM TYPE	(1)	(2)	(3)	(4)	(5)	(6)	(7)
MEASUREMENT FAILED					X		
MEASUREMENT ERROR							
MEASUREMENT OUTDATED							
INTERFACE BAD							
BSI BAD							
TESTING LOCKED OUT				X			
TEST NOT ATTEMPTED							

NOTE: THIS TABLE IS DISPLAYED THE FIRST TIME THE OPERATOR PRESSES THE PROBLEM UNITS FUNCTION KEY. THE NEXT TIME HE PRESSES THE KEY A SIMILAR TABLE FOR BSI 2 WILL BE PRESENTED, THEN FOR BSI 3 AND THEN BACK TO BSI 1.

FIGURE B-2 BSI 1 PROBLEM UNITS DISPLAY

DISPLAY AREA

UNITS NEEDING UPDATE   CURRENT TIME 1910

BSI 1		BSI 2		BSI 3	
UNIT	TIME	UNIT	TIME	UNIT	TIME
R-1051 (1)	1925	SRC-20(1)	1935		
R-1051 (2)	1950				

UNIT STATUS WILL BE OUTDATED AT SPECIFIED TIME

NOTE: THIS TABLE IS DISPLAYED WHEN THE UPDATE NEEDED FUNCTION KEY IS PRESSED.

FIGURE B-3 UNITS NEEDING STATUS UPDATE DISPLAY

DISPLAY AREA

LIST OF LOCKED OUT UNITS		
BSI 1 UNITS	BSI 2 UNITS	BSI 3 UNITS
R-1051 (4) R-1051 (2)	SRC-20 (3) SRC-20 (5)	

NOTE: THIS TABLE IS DISPLAYED WHEN THE LOCKED OUT FUNCTION KEY IS PRESSED.

FIGURE B-4 LOCKED OUT UNITS DISPLAY

DISPLAY AREA

BSI 2 SRC-20 (1) STATUS = PASS

PARAM	STATUS	MEASURED VALUE	FAIL LIMITS	PASS LIMITS	GOOD LIMITS
RCVR SENS	GOOD				
POWER OUTPUT	GOOD				
MODU-LATION	PASS				
VSWR	GOOD				

NOTE: NORMAL DISPLAY - MEASURED VALUES AND LIMIT VALUES FOR ALL PARAMETERS TESTED WILL BE FILLED IN.

DISPLAY AREA

BSI 2	SRC-20 (1)	a message will appear here

NOTE: ABNORMAL TEST REPORT DISPLAY - A MESSAGE WILL BE PROVIDED STATING THE SITUATION THAT PREVENTED NORMAL TESTING. EXAMPLES ARE: TESTING LOCKED OUT, INTERFACE DOWN

NOTE: THIS TABLE IS PRESENTED AUTOMATICALLY IN RESPONSE TO AN ACTION AT THE LAT TO INITIATE TESTING OF THE UNIT, AND WHEN THE BSI 2 UNITS FUNCTION KEY IS PRESSED. SUBSEQUENT PRESSING OF THE KEY THROUGH DISPLAYS FOR THE OTHER BSI 2 UNITS.

FIGURE B-5 TEST REPORT FOR BSI 2 UNITS

Appendix C

LED Display Characteristics

HEWLETT PACKARD COMPONENTS

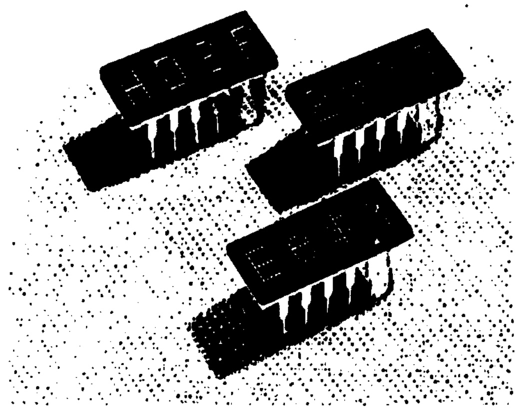
FOUR CHARACTER SOLID STATE ALPHANUMERIC DISPLAY

HDSP-2000

TECHNICAL DATA APRIL 1978

Features

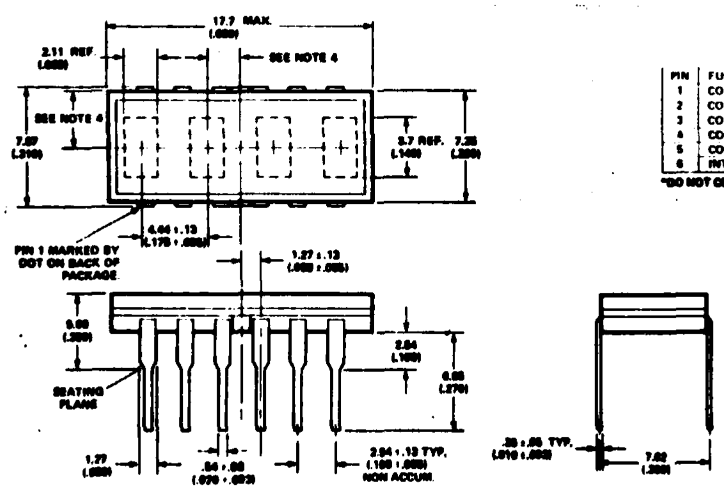
- **INTEGRATED SHIFT REGISTERS WITH CONSTANT CURRENT DRIVERS**
- **CERAMIC 7.62 mm (.3 in.) DIP**
  Integral Red Glass Contrast Filter
- **WIDE VIEWING ANGLE**
- **END STACKABLE 4 CHARACTER PACKAGE**
- **PIN ECONOMY**
  12 Pins for 4 Characters
- **TTL COMPATIBLE**
- **5x7 LED MATRIX DISPLAYS FULL ASCII CODE**
- **RUGGED, LONG OPERATING LIFE**
- **CATEGORIZED FOR LUMINOUS INTENSITY**
  Assures Ease of Package to Package Brightness Matching



Description

The HP HDSP-2000 display is a 3.8mm (0.15 inch) 5x7 LED array for display of alphanumeric information. The device is available in 4 character clusters and is packaged in a 12-pin dual-in-line type package. An on-board SIPO (serial-in-parallel-out) 7 bit shift register associated with each digit controls constant current LED row drivers. Full character display is achieved by external column strobing. The constant current LED drivers are externally programmable and typically capable of sinking 13.5mA peak per diode. Applications include interactive I/O terminals, point of sale equipment, portable telecommunications gear, and hand held equipment requiring alphanumeric displays.

Package Dimensions



PIN	FUNCTION	PIN	FUNCTION
1	COLUMN 1	7	DATA OUT
2	COLUMN 2	8	V_B
3	COLUMN 3	9	V_{CC}
4	COLUMN 4	10	CLOCK
5	COLUMN 5	11	GROUND
6	INT. CONNECT*	12	DATA IN

*DO NOT CONNECT OR USE

NOTES:
1. DIMENSIONS IN mm (inches).
2. UNLESS OTHERWISE SPECIFIED THE TOLERANCE ON ALL DIMENSIONS IS ±.38 mm (±.015")
3. LEAD MATERIAL IS GOLD PLATED COPPER ALLOY.
4. CHARACTERS ARE CENTERED WITH RESPECT TO LEADS WITHIN ±.13mm (±.005").

Absolute Maximum Ratings

Supply Voltage V_{CC} to Ground .... −0.5V to 6.0V
Inputs, Data Out and V_B .... −0.5V to V_{CC}
Column Input Voltage, V_{COL} .... −0.5V to +6.0V
Free Air Operating Temperature
Range, T_A[2] .... −20°C to +70°C

Storage Temperature Range, T_S ..... −55°C to +100°C
Maximum Allowable Package Dissipation
at T_A = 25°C[1,2,6] .... 1.70 Watts
Maximum Solder Temperature 1.59mm (.063")
Below Seating Plane t<5 secs .... 260°C

Recommended Operating Conditions

Parameter	Symbol	Min.	Nom.	Max.	Units
Supply Voltage	V_{CC}	4.75	5.0	5.25	V
Data Out Current, Low State	I_{OL}			1.6	mA
Data Out Current, HighState	I_{OH}			−0.5	mA
Column Input Voltage, Column On	V_{COL}	2.6		V_{CC}	V
Setup Time	t_{setup}	70	45		ns
Hold Time	t_{hold}	30	0		ns
Width of Clock	$t_{w(Clock)}$	75			ns
Clock Frequency	f_{clock}	0		3	MHz
Clock Transition Time	t_{THL}			200	ns
Free Air Operating Temperature Range	T_A	−20		70	°C

Electrical Characteristics Over Operating Temperature Range

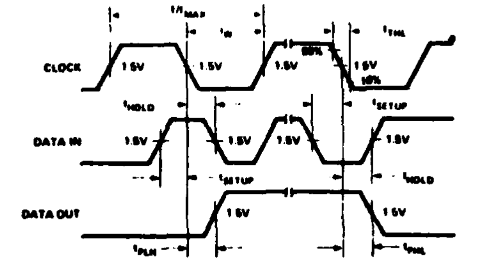
(Unless otherwise specified.)

Description		Symbol	Test Conditions		Min.	Typ.*	Max.	Units
Supply Current		I_{CC}	V_{CC} = 5.25V, V_{CLOCK} = V_{DATA} = 2.4V, All SR Stages = Logical 1	V_B = 0.4V		45	60	mA
				V_B = 2.4V		73	95	mA
Column Current at any Column Input		I_{COL}	V_{CC} = V_{COL} = 5.25V, All SR Stages = Logical 1	V_B=0.4V			1.5	mA
Column Current at any Column Input		I_{COL}		V_B=2.4V		335	410	mA
Peak Luminous Intensity per LED[3,7] (Character Average)		I_{vPEAK}	V_{CC} = 5.0V, V_{COL} = 3.5V, T_i = 25°C[4] V_B=2.4V		105	200		µcd
V_B, Clock or Data Input Threshold High		V_{IH}	V_{CC} = V_{COL} = 4.75V		2.0			V
V_B, Clock or Data Input Threshold Low		V_{IL}					0.8	V
Input Current Logical 1	V_B, Clock	I_{IH}	V_{CC} = 5.25V, V_{IH} = 2.4V			20	80	µA
	Data In	I_{IH}				10	40	µA
Input Current Logical 0	V_B,Clock	I_{IL}	V_{CC} = 5.25V, V_{IL} = 0.4V			-500	-800	µA
	Data In	I_{IL}				-250	-400	µA
Data Out Voltage		V_{OH}	V_{CC} = 4.75V, I_{OH} = −0.5mA, V_{COL} = 0V		2.4	3.4		V
		V_{OL}	V_{CC} = 4.75V, I_{OL} = 1.6mA, V_{COL} = 0V			0.2	0.4	V
Power Dissipation Per Package**		P_D	V_{CC} = 5.0V, V_{COL} = 2.6V, 15 LEDs on per character, V_B = 2.4V			0.66		W
Peak Wavelength		λ_{PEAK}				655		nm
Dominant Wavelength[5]		λ_d				639		nm

*All typical values specified at V_{CC} = 5.0V and T_A = 25°C unless otherwise noted.
**Power dissipation per package with 4 characters illuminated.

NOTES:
1. Maximum absolute dissipation is with the device in a socket having a thermal resistance from pins to ambient of 35°C/watt.
2. The device should be derated linearly above 25°C at 16mW/°C (see Electrical Description on page 3).
3. The characters are categorized for Luminous Intensity with the intensity category designated by a letter code on the bottom of the package.
4. T_i refers to the initial case temperature of the device immediately prior to the light measurement.
5. Dominant wavelength λ_d is derived from the CIE chromaticity diagram, and represents the single wavelength which defines the color of the device.
6. Maximum allowable dissipation is derived from V_{CC} = V_B = V_{COL} = 5.25 Volts, 20 LEDs on per character.
7. The luminous sterance of the LED may be calculated using the following relationships:

L_v (Lux) = I_v (Candela)/A (Metre)
L_v (Footlamberts) = πI_v (Candela)/A (Foot)
A = 5.3 x 10 M = 5.8 x 10 (Foot)



Parameter	Condition	Min.	Typ.	Max.	Units
f_{max} Max. CLOCK Rate		3			MHz
t_{PLH}, t_{PHL} Propagation delay CLOCK to DATA OUT	C_L = 15pF R_L=2.4KΩ			90	ns

Figure 1. Switching Characteristics. (V_{CC} = 5V, T_A = -20°C to +70°C)

Mechanical and Thermal Considerations

The HDSP-2000 is available in a standard 12 lead ceramic-glass dual in-line package. It is designed for plugging into DIP sockets or soldering into PC boards. The packages may be horizontally or vertically stacked for character arrays of any desired size.

The -2000 can be operated over a wide range of temperature and supply voltages. Full power operation at T_A = 25°C (V_{CC} = V_B = V_{COL} = 5.25V) is possible by providing a total thermal resistance from the seating plane of the pins to ambient of 35°C/W/cluster maximum. For operation above T_A = 25°C, the maximum device dissipation should be derated above 25°C at 16mW/°C (see Figure 2). Power derating can be achieved by either decreasing V_{COL} or decreasing the average drive current through pulse width modulation of V_B.

The -2000 display has an integral contrast enhancement filter in the glass lens. Additional front panel contrast filters may by desirable in most actual display applications. Some suggested filters are Panelgraphic Ruby Red 60, SGL Homalite H100-1605 and Plexiglass 2423. Hewlett-Packard Application Note 964 treats this subject in greater detail.

Post solder cleaning may be accomplished using water, Freon/alcohol mixtures formulated for vapor cleaning processing (up to 2 minutes in vapors at boiling) or Freon/alcohol mixtures formulated for room temperature cleaning. Suggested solvents: Freon TF, Freon TE, Genesolv DI-15, Genesolv DE-15.

Electrical Description

The HDSP-2000 four character alphanumeric display has been designed to allow the user maximum flexibility in interface electronics design. Each four character display module features Data In and Data Out terminals arrayed for easy PC board interconnection such that display strings of up to 80 digits may be driven from a single character generator. Data Out represents the output of the 7th bit of digit number 4 shift register. Shift register clocking occurs on the high to low transition of the Clock input. The like columns of each character in a display cluster are tied to a single pin. Figure 5 is the block diagram for the HDSP-2000. High true data in the shift register enables the output current mirror driver stage associated with each row of LEDs in the 5x7 diode array.

The reference current for the current mirror is generated from the output voltage of the V_B input buffer applied across the resistor R. The TTL compatible V_B input may either be tied to V_{CC} for maximum display intensity or pulse width modulated to achieve intensity control and reduction in power consumption.

The normal mode of operation is depicted in the block diagram of Figure 6. In this circuit, binary input data for digit 4, column 1 is decoded by the 7 line output ROM and then loaded into the 7 on board shift register locations 1 through 7 through a parallel-in-serial-out shift register. Column 1 data for digits 3, 2 and 1 is similarly decoded and shifted into the display shift register locations. The column 1 input is now enabled for an appropriate period of time, T. A similar process is repeated for columns 2, 3, 4 and 5. If the time necessary to decode and load data into the shift register is t, then with 5 columns, each column of the display is operating at a duty factor of:

$$\text{D.F.} = \frac{T}{5(t+T)}$$

The time frame, t + T, allotted to each column of the display is generally chosen to provide the maximum duty factor consistent with the minimum refresh rate necessary

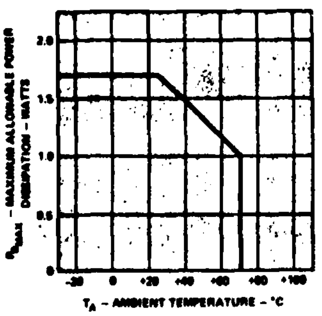


Figure 2. Maximum Allowable Power Dissipation vs. Temperature.

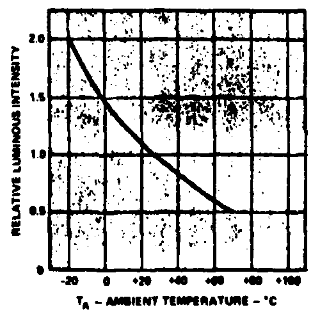


Figure 3. Relative Luminous Intensity vs. Temperature.

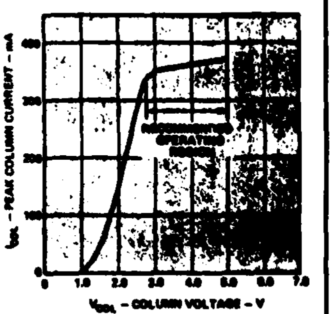


Figure 4. Peak Column Current vs. Column Voltage.

to achieve a flicker free display. For most strobed display systems, each column of the display should be refreshed (turned on) at a minimum rate of 100 times per second.

With 5 columns to be addressed, this refresh rate then gives a value for the time t + T of:

$1/[5 \times (100)] = 2$ msec.

If the device is operated at 3.0 MHz clock rate maximum, it is possible to maintain $t \ll T$. For short display strings, the duty factor will then approach 20%. For longer display strings operation at column duty factors of less than 10% will still provide adequate display intensity in most applications. For further applications information, refer to HP Application Note 966, Application Bulletin No. 51 and Application Bulletin No. 55.

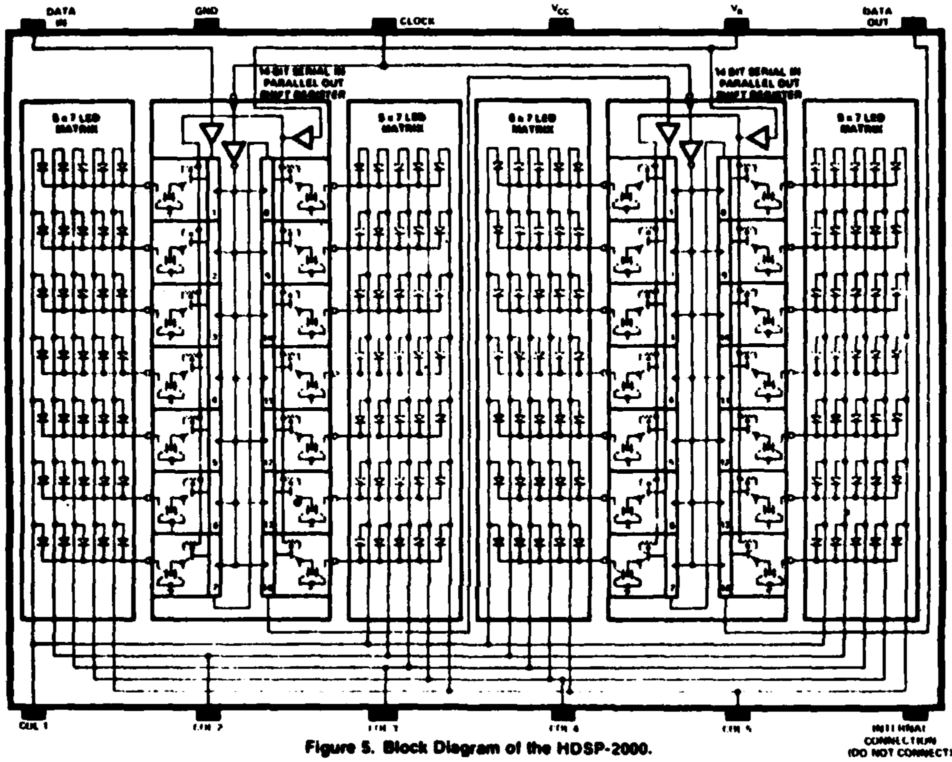


Figure 5. Block Diagram of the HDSP-2000.

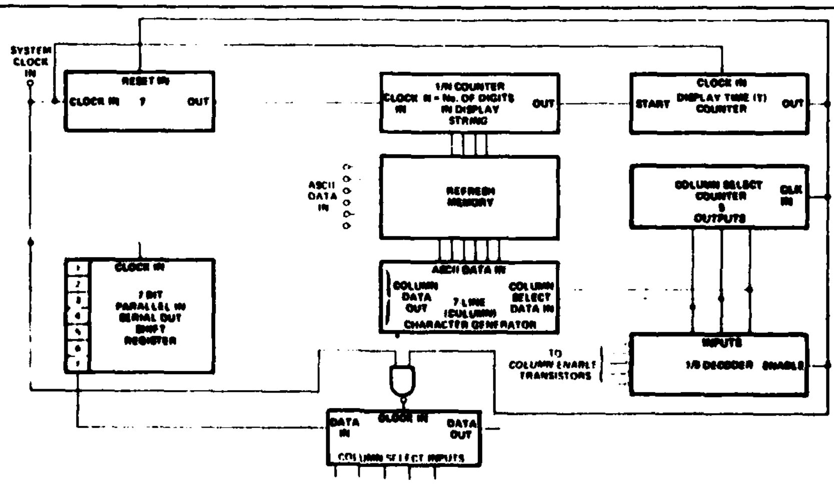


Figure 6. Block Diagram of a Basic Display System.

HEWLETT PACKARD

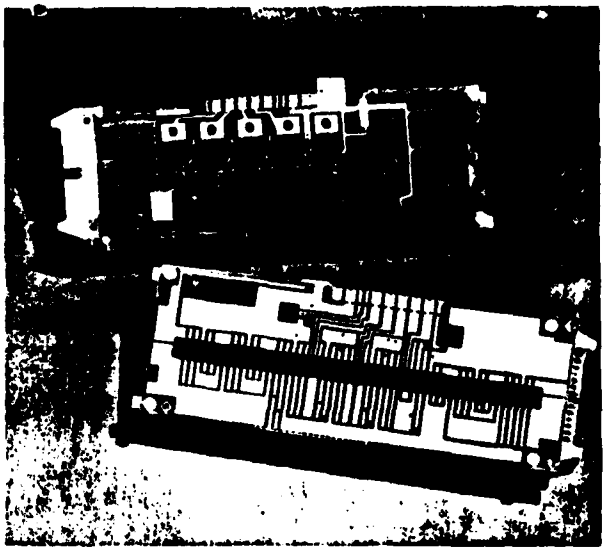
COMPONENTS

5 x 7 DOT MATRIX ALPHANUMERIC DISPLAY SYSTEM

HDSP-2416
HDSP-2424
HDSP-2432
HDSP-2440
HDSP-2470
HDSP-2471
HDSP-2472

TENTATIVE DATA SEPTEMBER 1978

Features



- COMPLETE ALPHANUMERIC DISPLAY SYSTEM UTILIZING THE HDSP-2000 DISPLAY
- CHOICE OF 64, 128, OR USER DEFINED ASCII CHARACTER SET
- CHOICE OF 16, 24, 32, or 40 ELEMENT DISPLAY PANEL
- MULTIPLE DATA ENTRY FORMATS — Left, Right, RAM, or Block Entry
- EDITING FEATURES THAT INCLUDE CURSOR, BACKSPACE, FORWARDSPACE, INSERT, DELETE, AND CLEAR
- DATA OUTPUT CAPABILITY
- SINGLE 5.0 VOLT POWER SUPPLY
- TTL COMPATIBLE
- EASILY INTERFACED TO A KEYBOARD OR A MICROPROCESSOR

Description

The HDSP-24XX series of alphanumeric display systems provides the user with a completely supported 5 x 7 dot matrix display panel. These products free the user's system from display maintenance and minimize the interaction normally required for alphanumeric displays. Each alphanumeric display system is composed of two component parts:

1. An alphanumeric display controller which consists of a preprogrammed microprocessor plus associated logic, which provides decode, memory, and drive signals necessary to properly interface a user's system to an HDSP-2000 display. In addition to these basic display support operations, the controller accepts data in any of four data entry formats and incorporates several powerful editing routines.
2. A display panel which consists of HDSP-2000 displays matched for luminous intensity and mounted on a P.C. board designed to have low thermal resistance.

These alphanumeric display systems are attractive for applications such as data entry terminals, instrumentation, electronic typewriters, and other products which require an easy to use 5 x 7 dot matrix alphanumeric display system.

PART NUMBER	DESCRIPTION
Display Boards	
HDSP-2416	Single-line 16 character display panel utilizing the HDSP-2000 display
HDSP-2424	Single-line 24 character display panel utilizing the HDSP-2000 display
HDSP-2432	Single-line 32 character display panel utilizing the HDSP-2000 display
HDSP-2440	Single-line 40 character display panel utilizing the HDSP-2000 display
Controller Boards	
HDSP-2470	HDSP-2000 display interface incorporating a 64 character ASCII decoder
HDSP-2471	HDSP-2000 display interface incorporating a 128 character ASCII decoder
HDSP-2472	HDSP-2000 display interface without ASCII decoder. Instead, a 24 pin socket is provided to accept a custom 128 character set from a user programmed 1K x 8 PROM.

When ordering, specify one each of the Controller Board and the Display Board for each complete system.

Absolute Maximum Ratings

Supply Voltage V_{CC} to Ground .... -0.5V to 6.0V
Inputs, Data Out and V_B .... -0.5V to V_{CC}
Column Input Voltage, V_{COL} .... -0.5V to +6.0V
Free Air Operating Temperature
Range, T_A[1] .... 0°C to +55°C
Storage Temperature Range, T_S .... -55°C to +100°C

Recommended Operating Conditions

Parameter	Symbol	Min.	Norm.	Max.	Units
Supply Voltage	V_{CC}	4.75	5.0	5.25	V
Column Input Voltage, Column On	V_{COL}	2.6			V
Setup Time	t_{SETUP}	70	45		ns
Hold Time	t_{HOLD}	30	0		ns
Width of Clock	$t_{W(CLOCK)}$	75			ns
Clock Frequency	f_{CLOCK}	0		3	MHz
Clock Transition Time	t_{THL}			200	ns
Free Air Operating[1] Temperature Range	T_A	0		55	°C

Electrical Characteristics Over Operating Temperature Range

(Unless otherwise specified)

Parameter		Symbol	Min.	Typ.*	Max.	Units	Conditions	
Supply Current		I_{CC}		45n	60n[2]	mA	V_{CC} = 5.25V $V_{CLOCK}=V_{DATA}$=2.4V All SR Stages = Logical 1	V_B = 0.4V
		I_{CC}		73n	95n	mA		V_B = 2.4V
Column Current at any Column Input		I_{COL}			1.5n	mA	$V_{CC} = V_{COL}$ = 5.25V All SR Stages = Logical 1	V_B = 0.4V
		I_{COL}		335n	410n	mA		V_B = 2.4V
Peak Luminous Intensity per LED (Character Average)		$I_{V\ PEAK}$	105	200		µcd	V_{CC} = 5.0V, V_{COL} = 3.5V T_j = 25°C[3], V_B = 2.4V	
V_B, Clock or Data Input Threshold High		V_{IH}	2.0			V	$V_{CC} = V_{COL}$ = 4.75V	
V_B, Clock or Data Input Threshold Low		V_{IL}			0.8	V		
Input Current Logical 1	V_B, Clock	I_{IH}			80	µA	V_{CC} = 5.25V, V_{IH} = 2.4V	
	Data In	I_{IH}			40	µA		
Input Current Logical 0	V_B, Clock	I_{IL}		-500	-800	µA	V_{CC} = 5.25V, V_{IL} = 0.4V	
	Data In	I_{IL}		-250	-400	µA		
Power Dissipation Per Board[4]		P_D		0.66n		W	V_{CC} = 5.0V, V_{COL} = 2.6V 15 LED's on per Character, V_B = 2.4V	

*All typical values specified at V_{CC} = 5.0V and T_A = 25°C unless otherwise noted.

NOTES:
1. Operation above 55°C (70°C MAX) may be achieved by the use of forced air (150 fpm normal to component side of HDSP-247X controller board at sea level).
2. *n = number of HDSP-2000 packages*
   HDSP-2416 n = 4
   HDSP-2424 n = 6
   HDSP-2432 n = 8
   HDSP-2440 n = 10
3. T_j refers to initial case temperature immediately prior to the light measurement.
4. Power dissipation with all characters illuminated.

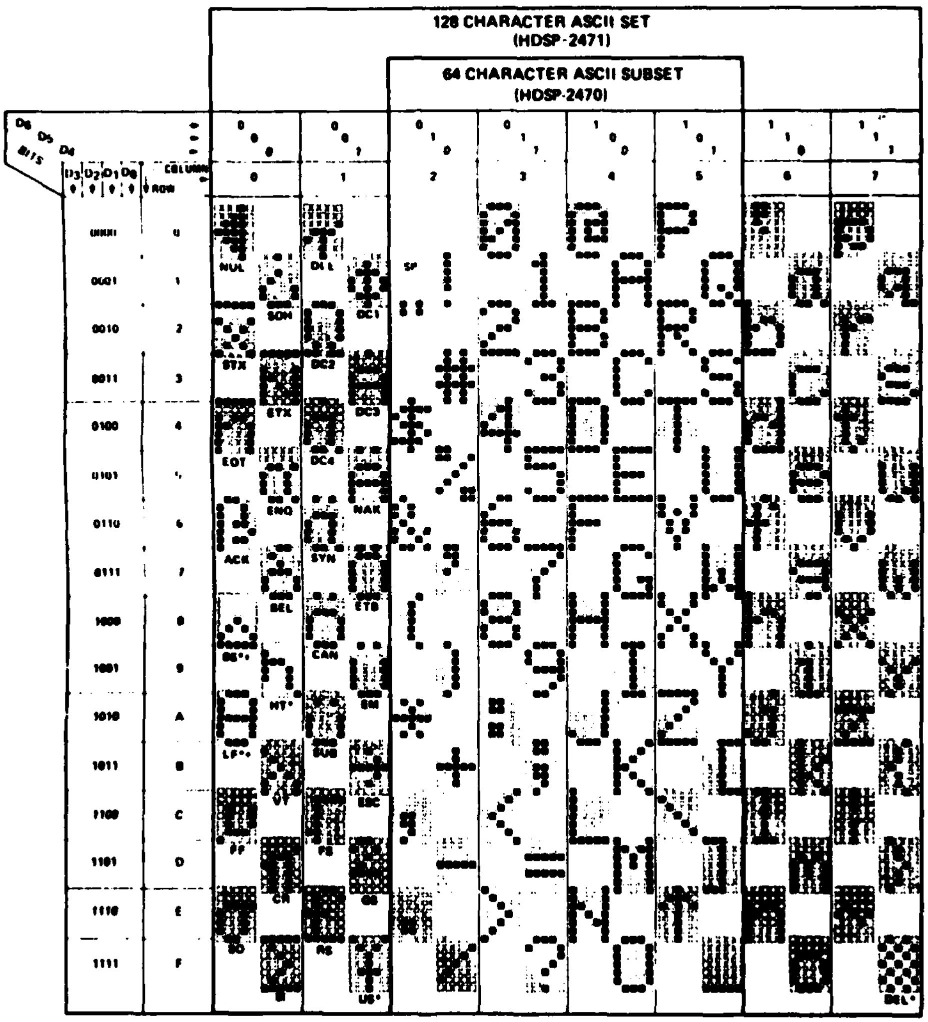
If D_7 is a logic low when the DATA IN lines are read, the controller will interpret D_6-D_0 as standard ASCII data to be stored, decoded and displayed. The system accepts seven bit ASCII for all three versions. However, the HDSP-2470 system displays only the 64 character subset (20_{16} (space) to $5F_{16}$ (_)) and ignores all ASCII characters outside this subset with the exception of those characters defined as display commands. These display commands are shown in Figure 5. Displayed character sets for the HDSP-2470/-2471 systems are shown in Figure 6.

DATA WORD:	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	
ASCII ASSIGNMENT	0	A	A	A	A	A	A	A	DISPLAY COMMAND
LF		0	0	0	1	0	1	0	CLEAR
BS		0	0	0	1	0	0	0	BACKSPACE CURSOR
HT		0	0	0	1	0	0	1	FORWARDSPACE CURSOR
US		0	0	1	1	1	1	1	INSERT CHARACTER
DEL		1	1	1	1	1	1	1	DELETE CHARACTER

CLEAR and BACKSPACE CURSOR: Valid in Right Entry Mode

CLEAR through DELETE CHARACTER: Valid in Left Entry Mode

Figure 5. Display Commands for the HDSP-2470/-2471/-2472 Alphanumeric Display Controller.



*DISPLAY COMMANDS WHEN USED IN LEFT ENTRY
+DISPLAY COMMANDS WHEN USED IN RIGHT ENTRY

Figure 6. Display Font for the HDSP-2470 (64 Character ASCII Subset), and HDSP-2471 (128 Character ASCII Set) Alphanumeric Display Controller.

Appendix D

This appendix provides a list (Table D-1) for checking the design characteristics against human engineering design criteria set forth in MIL-STD-1472B. The list is only partially complete. This report does not provide all the details of the system design and therefore it cannot provide for a complete evaluation of the design against MIL-STD-1472B. It is the intent of this appendix to illustrate how the list has been used for evaluating the design features described in this report, and how it will be used to evaluate the other design characteristics as they are established. A check (✓) on the list indicates compliance, a 0 indicates a discrepancy, and an NA indicates not applicable. The first page of the list goes through MIL-STD-1472B paragraph by paragraph as would be done before acceptance of the overall design. The second page selects paragraphs that pertain to design features included in this report.

TABLE D-1 MIL-STD-1472B CHECK-OFF LIST (SHEET 1 OF 2)

MIL-STD-1472B PARAGRAPH	LAT	BSIs	MIL-STD-1472B PARAGRAPHS	LAT	BSIs
5.1.1.1	✓	✓	5.2.1.2.7	✓	✓
5.1.1.2	✓	✓	5.2.1.2.8	✓	✓
5.1.1.3	✓	✓	5.2.1.3.1	✓	✓
5.1.1.4	✓	✓	5.2.1.3.2	✓	✓
5.1.1.5	✓	✓	5.2.1.3.3	✓	✓
5.1.2.1	NA	✓	5.2.1.3.4	✓	✓
5.1.2.1.1 (1)	NA	O	5.2.1.3.5	✓	✓
5.1.2.1.2	✓	✓	5.2.1.3.6	✓	✓
5.1.2.1.3	NA	✓	5.2.1.3.7	✓	✓
5.1.2.1.4	NA	✓	5.2.1.3.8	NA	NA
5.1.2.2	NA	NA	5.2.1.3.9	NA	NA
5.1.2.3	NA	✓	5.2.1.3.10	✓	✓
5.1.2.3.1	NA	NA	5.2.1.3.11	✓	✓
5.1.2.3.2	NA	NA	5.2.1.3.12	✓	✓
5.1.2.3.3	NA	NA	5.2.1.3.13	NA	NA
5.1.2.3.4	NA	NA	5.2.1.4	NA	NA
5.1.2.3.5	NA	NA	5.2.2.1.1	NA	✓
5.1.2.3.6	NA	NA	5.2.2.1.2	NA	✓
5.1.3	NA	NA	5.2.2.1.3	NA	✓
5.1.4	NA	NA	5.2.2.1.4	NA	✓
5.2.1	✓	✓	5.2.2.1.5	NA	NA
5.2.1.1	✓	✓	5.2.2.1.6	NA	✓
5.2.1.2.1	✓	✓	5.2.2.1.7	NA	NA
5.2.1.2.2	✓	✓	5.2.2.1.8	NA	✓
5.2.1.2.3	✓	✓	5.2.2.1.9	NA	✓
5.2.1.2.4	✓	✓	5.2.2.1.10	NA	NA
5.2.1.2.5	✓	✓	5.2.2.1.11	NA	✓
5.2.1.2.6	✓	✓	5.2.2.1.12	NA	NA

(1) THE BSI (SRC-20) USES A BOTTOM-TO-TOP SEQUENCE ORDER FOR SELECTING THE TEST AND UNIT. THIS IS DONE TO AVOID OBSCURING THE STATUS DISPLAY LIGHTS WITH THE OPERATOR'S ✓ HAND, AND TO ENABLE PLACING THESE DISPLAY LIGHTS ADJACENT TO THE CONTROL (PER PAR. 5.1.1.2).

TABLE D-1 MIL-STD-1472B CHECK-OFF LIST (SHEET 2 OF 2)

MIL-STD-1472B PARAGRAPH	LAT	BSIS
5.2.2.2	NA	NA
5.2.2.3.3	NA	O
5.4.1.1.4	✓	✓
5.4.1.3.1	NA	✓
5.4.1.3.2 (1)	NA	O
5.4.1.3.4	NA	✓
5.4.1.3.7	✓	✓
5.4.1.8.1	✓	✓
5.4.3.1.1.6	✓	✓
5.4.3.1.4.1	NA	✓
5.4.3.1.4.3	NA	✓
5.5.1.1	NA	✓
5.5.1.2	NA	✓
5.5.2.1.1	NA	✓
5.5.2.2	NA	✓
5.5.2.3	NA	✓

MIL-STD-1472B PARAGRAPH	LAT	BSIS
5.5.3.2	NA	✓
5.5.4.2	NA	✓
5.5.4.3	NA	✓
5.5.5.4 (2)	NA	O
5.5.5.12	NA	✓
5.5.5.13	NA	✓
5.5.6.2.1	NA	✓
5.5.6.2.2	NA	✓
5.5.6.2.3	NA	✓
5.5.6.2.4	NA	✓

(2) THE WIDTH-TO-HEIGHT RATIOS OF SOME LETTERS ON THE IIC PUSHBUTTONS MAY BE LESS THAN REQUIRED. TESTS WILL BE MADE TO SEE IF THESE LETTERS CAN BE READ ACCURATELY. IF NOT, THEN THE LABELS WILL BE PLACED BELOW THE PUSHBUTTON.

Appendix E

MIL-STD-12C, Abbreviations for Use on

Drawings, Specifications, Standards and in Technical Documents

(excerpts)

TERM	ABBREVIATION	
radio direction finding	RDF	rdf
radio frequency	RF	rf
radio frequency amplification by stimulated emission of radiation	RASER	raser
radio-frequency choke	RFC	rfc
radio-frequency interference	RFI	rfi
radio interference field intensity	RIFI	rifi
radio operator	RAD OPR	rad opr
radio teletypewriter	RTTY	rtty
radioactive	RAACT	raact
radioactive liquid waste	RALW	ralw
*radiographic inspection	RAD INSP	rad insp
radiological	RADL	radl
radiological defense	RADDEF	raddef
radiological warfare	RADWAR	RADWAR
radius	RAD	rad
*rail	R	r
railing	RLG	rlg
railroad	RR	rr
railway	RY	ry
raintight	RT	rt
rainwater conductor	RWC	rwc
*raised	RSD	rsd
raised face	RF	rf
raised face diameter	RFD	rfd
raised face height	RFH	rfh
ramjet	RMJ	rmj
random	RNDM	rndm
random access discrete address system	RADAS	radas
range	RNG	rng
range height indicator	RHI	rhi
range light	RA LT	ra lt
range marks	RM	rm
range rate indicator	RRI	rri
rapid rectilinear	RR	rr
*ratchet	RCHT	rcht
rate	RT	rt
rate of change	RC	rc
rateau	RAT	rat
rating	RTG	rtg
ratio	R	r
rattail	RTTL	rttl
raw material	RM	rm
raw tape write submodule	RTWS	rtws
raw water	RW	rw
rawhide	RWHD	rwhd
rayon	RYN	ryn
rayon (insul)	RA	ra
reactance	REAC	reac
reaction	RCTN	rctn
reactivate	REACTVT	reactvt
reactive factor meter	RFM	rfm
reactive volt-ampere meter	RVA	rva
reactor	REAC	reac
reactor compartment	RC	rc
reactor core	RCO	rco
read	RD	rd
read-write (head)	R-W	r-w
reader	RDR	rdr
reader common contact	RCC	rcc
reader tape contact	RTC	rtc
readiness	RDNS	rdns
reading	RDNG	rdng
readout	RDOUT	rdout
readout and relay	R/R	r/r
ready	RDY	rdy
ready service	RS	rs
real and not-corrected input data	RANCID	rancid
real time	RT	rt
real-time input-output transducer	RIOT	riot
reamer	RMR	rmr
rear connection	RC	rc
rear view	RV	rv
*reassemble	REASSEM	reassem
rebabbit	RBBT	rbbt
recalculated	RECALC	recalc
recall	RCL	rcl
receive	RCV	rcv
receive-only tape perforator	ROTR	rotr
*received	RCVD	rcvd
receiver	RCVR	rcvr
receiver-transmitter	RT	rt
receiving	RCVG	rcvg
*receptacle	RCPT	rcpt
*reception	RCPTN	rcptn
recess	REC	rec
recessed	REC	rec
recharger	RECHRG	rechrg
reciprocating	RECIP	recip

*Abbreviation changed

TERM	ABBREVIATION	
sense	SEN	sen
sense amplifier	SA	sa
sensitive	SENS	sens
sensitivity	SENS	sens
sensitivity time control	STC	stc
sensitized	SNTZD	sntzd
sensitized material print	SMP	smp
sensitizing	SNTZG	sntzg
sensor	SNSR	snsr
separate	SEP	sep
separator	SEP	sep
sequence	SEQ	seq
sequence check	SEQ CHK	seq chk
sequential coding	SECO	seco
serial	SER	ser
serial number	SERNO	serno
series	SER	ser
*series relay	SRLY	srly
serrate	SERR	serr
serrated	SERR	serr
*service	SVCE	svce
service bulletin	SB	sb
service ceiling	SRVCLG	srvclg
service fuel oil	SFO	sfo
service sink	SS	ss
service, sort and merge	SESAME	sesame
serving	SERG	serg
servo	SVO	svo
servomechanism	SERVO	servo
servomotor	SVMTR	svmtr
*setscrew	SSCR	sscr
setter	SETR	setr
setting	SET	set
*settling	SETLG	setlg
seven conductor	7/C	7/c
sewage	SEW	sew
sewer	SEW	sew
sexless (conductor)	SXL	sxl
sextant	SXTN	sxtn
shackle	SH	sh
shaft	SFT	sft
shaft alley	SA	sa
shaft center	SC	sc
shaft extension	SFT EXT	sft ext
shaft gear	SHFTGR	shftgr
shaft horsepower	SHP	shp
shakeproof	SHPRF	shprf
shank	SHK	shk
shape	SHP	shp
shaped charge	SC	sc
share	SH	sh
sharpener	SHRP	shrp
shear plate	SP	sp

TERM	ABBREVIATION	
shearing	SHRNG	shrng
sheathing	SHTHG	shthg
sheave	SHV	shv
sheet	SH	sh
sheeting	SH	sh
shell	SHL	shl
shell destroying	SD	sd
shellac	SHL	shl
shield	SHLD	shld
shield (electron device)	SH	SH
shielding	SHLD	shld
shift	SHF	shf
shift register	SR	sr
ship class	SHPCL	shpcl
ship control	SCONT	scont
ship course	SCOU	scou
ship distance	SDIS	sdis
Ship Draft Indicating System	SDIS	SDIS
ship draft indicator transmitter	SDIT	sdit
Ship Inertial Navigational System	SINS	SINS
ship parts control center	SPCC	spcc
ship service	SS	ss
ship service turbo generator	SSTG	sstg
ship speed	SSP	ssp
ship status	SHSTS	shsts
shipboard	SHPBD	shpbd
shipboard allowance list	SAL	sal
shipfitter	SFTR	sftr
shipment	SHPT	shpt
shipping	SHPNG	shpng
shipping container	SHCR	shcr
shock absorber	SH ABS	sh abs
shoemaker	SHMKR	shmkr
shop missile assembly and maintenance	SMSA	smsa
shop order	SO	so
*shore connection	SH CONN	sh conn
shore terminal box	STB	stb
shoreline	SHLN	shln
short circuit	SHORT	short
short-circuit ratio	SCR	scr
short leaf yellow pine	SLYP	slyp
short range navigation	SHORAN	shoran
short side	SHTSD	shtsd
short takeoff and landing	STOL	STOL
short taper	STPR	stpr

*Abbreviation changed

TERM	ABBREVIATION	
very high frequency omnidirectional and radio range	VOR	VOR
very long range	VLR	vlr
very low altitude	VLA	vla
very low frequency	VLF	vlf
very short takeoff and landing	VSTOL	VSTOL
vestibule	VEST	vest
vestigal sideband	VSB	vsb
vestigal sideband modulation	VSM	vsm
vibrate	VIB	vib
vibration	VIB	vib
Vickers hardness	VH	Vh
video	VID	vid
video amplifier	VIDAMP	vidamp
*video frequency	VIDF	vidf
video integration	VINT	VINT
village	VIL	vil
violet	VIO	vio
viscometer	VISMR	vismr
viscosity	VISC	visc
viscosity index	VI	vi
visible	VSBL	vsbl
visual	VIS	vis
*visual aural radio range	VARR	varr
visual flight rules	VFR	VFR
visual identification	VISID	visid
vital load center	VLC	vlc
vitreous	VIT	vit
vitrified clay	VC	vc
vitrified clay tile	VCT	vct
voice	VO	vo
voice actuated transmitter keyer inhibitor	ANTIVOX	ANTI VOX
voice coil	VC	vc
voice frequency	VF	vf
voice-operated device for automatic transmission	VODAT	vodat
voice operated transmitter keyer	VOX	VOX
voice tube	VT	vt
void	VD	vd
volt, alternating current	VAC	Vac
volt, direct current	VDC	Vdc
volt ohm milliammeter	VOM	vom
voltage	V	v
voltage adjusting rheostat	V ADJ R	v adj r
voltage control transfer	VCT	vct
voltage controlled oscillator	VCO	vco
voltage detector	VDET	vdet
voltage drop	VD	vd
voltage regulator	VR	vr
*voltage relay	VRLY	vrly
voltage standing wave ratio	VSWR	vswr
voltage-tunable magnetron	VTM	vtm
voltammeter	VAM	vam
voltmeter	VM	vm
voltmeter switch	VS	vs
volume	VOL	vol
volume indicator	VI	vi
volume of compartment	VC	vc
volume unit	VU	vu
volumetric	VLMTRC	vlmtrc
volute	VLT	vlt
*vulcanize	VULC	vulc
*wafer	WFR	wfr
wagon	WAG	wag
wagon box	WB	wb
wainscot	WA	wa
waiting	WTG	wtg
*wake light	WK LT	wk lt
wall board	WLB	wlb
wall hydrant	WH	wh
wall receptacle	WR	wr
wall vent	WV	wv
walseal	WLSL	wlsl
wanigan	WAN	wan
wardrobe	WRB	wrb
wardroom	WR	wr
warehouse	WHSE	whse
warhead	WARHD	warhd
warming	WM	wm
warning	WRN	wrn
warping	WRPG	wrpg
warranty	WARR	warr
wash bucket	WB	wb
wash fountain	WF	wf
Washburn and Moen Gage	W&M GA	W&M GA
*washer	WSHR	wshr
washing	WSHG	wshg
washroom	WR	wr
waste	W	w
waste pipe	WP	wp
waste stack	WS	ws
water	WTR	wtr
water chiller	WCHR	wchr
water closet	WC	wc
water-cooled	WCLD	wcld
water heater	WH	wh
water jacket	WJ	wj
water line	WL	wl
water meter	WM	wm

*Abbreviation changed

ABBREVIATION		TERM
NITSTL	nitstl	nitride steel
NK	nk	neck
NKL	nkl	nickel
NL CHG	nl chg	normal charge
NL LT	nl lt	net-laying light
NLG	nlg	nose landing gear
NLNR	nlnr	nonlinear
NLT	nlt	normal lube oil tank
NM	nm	noise meter
NM	nm	nonmetallic
NM	nm	nuclear magnetron
NMAG	nmag	nonmagnetic
NO	no	normally open
NO	no	number
NOCCC	noccc	no control circuit contacts
NOG	nog	numbering
NOL	nol	normal overload
NOM	nom	nominal
NOMAD	nomad	naval oceanographic meteorological automatic device
NOMEN	nomen	nomenclature
NONFLMB	nonflmb	nonflammable
NONSTD	nonstd	nonstandard
NONSYN	nonsyn	nonsynchronous
NOP	nop	number of passes
NORM	norm	normal
NORM	norm	normalize
NOSC	nosc	nonoscillating
NOZ	noz	nozzle
NP	NP	National pipe
NP	np	nickel plated
NP	np	nonprocurable
NP	np	nonpropelled
NPA	npa	normal pressure angle
NPET	npet	nonpetroleum
NPL	npl	nameplate
NPN	npn	negative-positive-negative (transistor)
NPRN	nprn	neoprene
NPS	NPS	Navy Primary Standards
NPSC	NPSC	straight thread (pipe couplings)
NPSF	NPSF	thread for press tight joints
NPSH	npsh	and nipples
NPSL	NPSL	locknut pipe thread
NPSM	npsm	joints
NPT	NPT	National taper pipe (thread)
NPTF	nptf	tight joints
NPTR	NPTR	taper pipe thread (railing fixtures)
NR	nr	nonreactive (relay)
NR	nr	nuclear reactor

ABBREVIATION		TERM
NRCP	nrcp	nonreinforced concrete pipe
NRD	nrd	nonreplenishable demand
NRETN	nretn	non-return
NRL	nrl	night ration locker
NRVSBL	nrvsbl	nonreversible
NRZ	nrz	non-return-to-zero
NS	NS	National special (thread)
NS	ns	near side
NS	ns	nickel steel
NSLF	nslf	nonself
NSS	NSS	Navy Secondary Standards
NST	nst	nonslip tread
NT	nt	navy type
NT	nt	nontight
NTC	ntc	negative temperature coefficient
NTN	ntn	neutron
NTP	ntp	normal temperature and pressure
NTPL	ntpl	nut plate
NTS	nts	negative torque signal
NTS	nts	not to scale
NTWK	ntwk	network
NTWT	ntwt	net weight
NUC	nuc	nuclear
NUM	num	numeral
NUM	num	numerical
NVR	nvr	no voltage release
NWG	NWG	National Wire Gage
NWT	nwt	nonwatertight
NYL	nyl	nylon
O TO O	o to o	out to out
O&R	o&r	overhaul and repair
O&S	o&s	otherwise specified
O/M	o/m	outside of metal
O/P	o/p	ozalid print
OA	oa	over-all
OAO	OAO	orbiting astronomical observatory
OBA	oba	oxygen breathing apparatus
OBE	obe	outerback end
OBJ	obj	object
OBJV	objv	objective
OBL	obl	oblique
OBRNR	obrnr	oil burner
OBS	obs	observe
OBS	obs	obsolete
OBSTN	obstn	obstruction
OBSV	obsv	observation
OBV	obv	obverse
OBW	obw	observation window
OC	oc	on center

ABBREVIATION		TERM
FD	fd	front of dash
FDB	fdb	field dynamic braking
FDB	fdb	forced-draft blower
FDBK	fdbk	feedback
FDC	fdc	fire-department connection
FDE	fde	field decelerator
FDFL	fdfl	fluid flow
FDI	fdi	field discharge
FDM	fdm	frequency division multiplex
FDN	fdn	foundation
FDP	fdp	full dog point
FDPL	fdpl	fluid pressure line
FDR	fdr	feeder
FDR	fdr	finder
FDR	fdr	fire door
FDRY	fdry	foundry
FDW	fdw	feed water
FDWL	fdwl	fiberboard, double wall
FEB	feb	functional electronic block
FED	Fed	Federal
FELR	felr	fealer
FELR	felr	feeler
FEM	fem	female
FER	fer	forward engine room
FER CON	fer con	ferrule-contact
FET	FET	field-effect transistor
FEXT	fext	fire extinguisher
FF	ff	file finish
FF	ff	fire fighting
FF	ff	flip flop
FF	ff	following
FF	ff	full field
FFAR	ffar	folding fin aircraft rocket
FFC	ffc	flip flop complementary
FFD	ffd	field forcing (decreasing)
FFI	ffi	field forcing (increasing)
FFILH	ffilh	flat fillister head
FFL	ffl	female flared
FFL	ffl	field failure
FFL	ffl	flip flop latch
FFL	ffl	front focal length
FG	fg	filament ground
FG	fg	frog
FGD	fgd	forged
FGR	fgr	finger
FH	fh	fire hose
FH	fh	full hard
FHC	fhc	fire-hose cabinet
FHP	fhp	fractional horsepower
FHP	fhp	friction horsepower
FHR	fhr	fire-hose rack

ABBREVIATION		TERM
FHT	fht	fully heat-treated
FHY	fhy	fire hydrant
FIC	fic	frequency interference control
FIG	fig	figure
FIL	fil	filament
FIL	fil	fillet
FIL	fil	fillister
FIL	fil	fuel injection line
FILH	filh	fillister head
FILL	fill	filling
FIP	fip	fuel injection pump
FIR	fir	fired
FIR	fir	fuel indicator reading
FIR	fir	full indicator reading
FK	fk	fork
FKD	fkd	forked
FL	fl	flashing
FL	fl	flat
FL	fl	flood (vent)
FL	fl	floor
FL	fl	floor line
FL	fl	flow
FL	fl	fluid
FL	fl	flush
FL	fl	flute lead
FL	fl	focal length
FL/W	fl/w	flash welding
FLD	fld	field
FLDG	fldg	folding
FLDK	fldk	flight deck
FLDNG	fldng	flooding
FLDO	fldo	final limit, down
FLDT	fldt	floodlight
FLEA	flea	flux logic element array
FLEX	flex	flexible
FLEX	flex	flexure
FLF	flf	final limit, forward
FLG	flg	flange
FLG	flg	flooring
FLGSTF	flgstf	flagstaff
FLGSTN	flgstn	flagstone
FLH	flh	final limit, hoist
FLH	flh	flat head
FLHLS	flhls	flashless
FLIDEN	fliden	flight data entry
FLKD	flkd	fluked
FLL	fll	final limit, lower
FLL	fll	flow line
FLLD	flld	full load
FLM	flm	flame
FLMB	flmb	flammable
FLMPRF	flmprf	flameproof
FLMPRS	flmprs	film processing
FLMSD	flmsd	film sound

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